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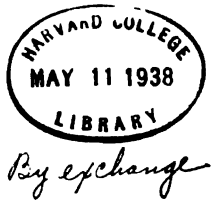

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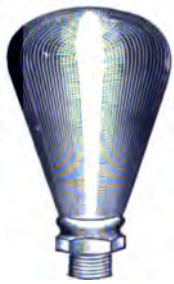

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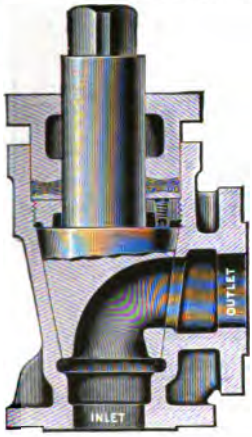

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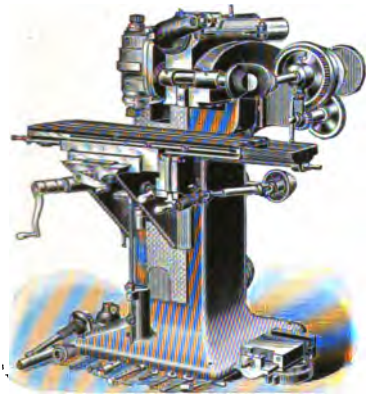

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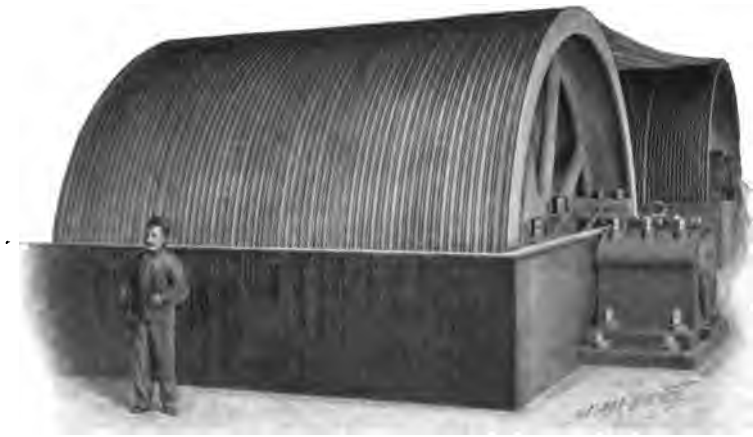

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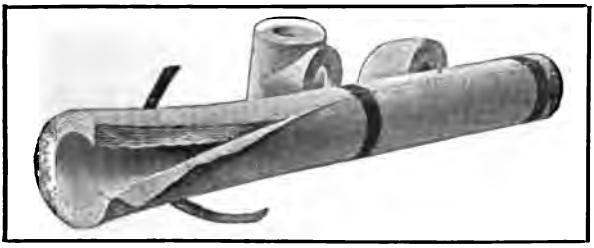

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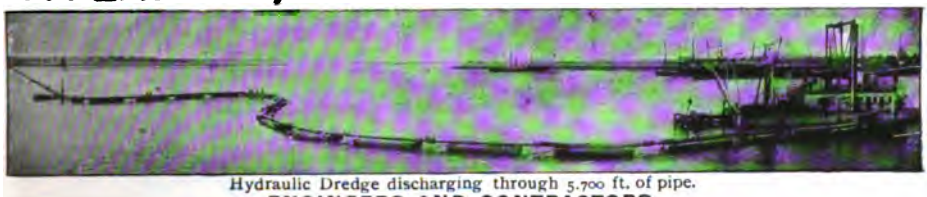

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Heats feed water to 250°. Increases Boiler capacity. Keeps reserve of HOT WATER for sudden calls. Saves Boiler repairs. Book "Green's Economizer" free.

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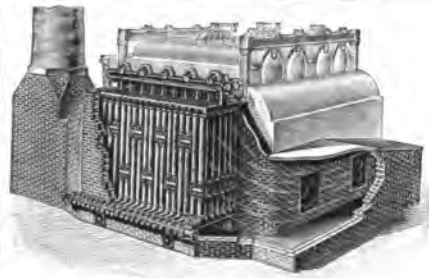

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128-138 MOTT STREET, NEW YORK

"ELECTRIC RAILWAYS."

Extract from "Halifax (Eng.) Guardian" Sept 2, 1899.

Councillor J. H. Whitley, J. P., Vice-Chairman of the Tramways Committee, and Mr. Street, Electrical Engineer for the Borough, left Halifax, on Wednesday, on a five weeks' trip to America. It is understood that they have gone there with the idea of learning something useful about electric tramways, which have been developed to a much greater extent in America than in this country. Some members of the Council, we hear, have suggested that they could have learned quite as much by reading the excellent articles that have recently been appearing in "Cassier's Magazine" as they will do by going to America.

The trip, will, however, be a very enjoyable one, and perhaps there is quite as much justification for it as the journey that is being made by a Bradford Corporation deputation to Roubaix to inspect certain sewage works. But, of course, the ratepayers grumble about the unnecessary expense in both cases. If they were only members of the deputation they might see things differently. By the way, some people are curious to know why the Vice-Chairman of the Tramways Committee is being sent instead of the Chairman. Perhaps he is able to stand salt water better.

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Vawter
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Accountants, Auditors,
Devisers of Business Systems,
Detailed Cost Analysis

Examine, audit and report upon the books, accounts and financial condition of corporations, firms and individuals; preparing all classes of accounts, balance sheets and financial statements, both with a view to verification and to improvement of systems.

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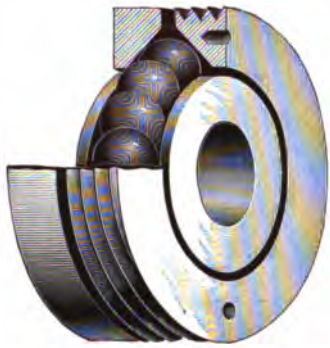

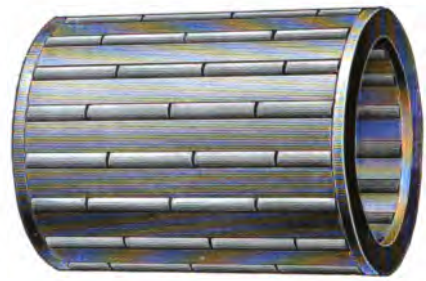

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NEW IDEAS. MODERN CONSTRUCTION
CONVENIENCE IN EVERY DETAIL

Descriptive Circulars Free. New Catalog Ready Jan. 1st.

The Hamilton Machine Tool Company

Hamilton, Ohio, U. S. A.

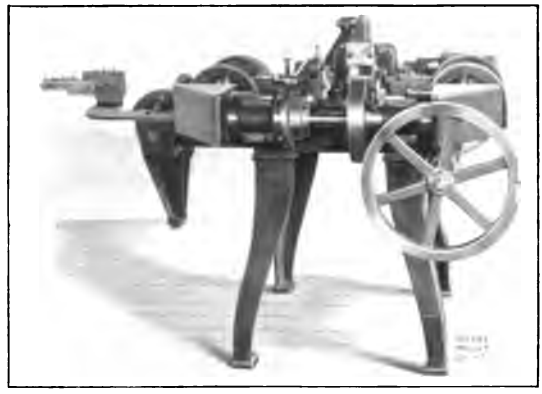
THE MANVILLE AUTOMATIC WIRE FORMING MACHINE

THIS form of machine was originally designed by the late E. J. Manville, in 1855, for making suspender and trouser-buckle frames. They did not come into general use until about 1870, when the demand for wire articles in various forms made a corresponding demand for machinery to produce them. At this time Mr. Manville placed on the market an improved and heavier machine. Since Mr. Manville's death this machine has been manufactured by his sons.

October, 1897, the Manville Brothers Company was incorporated, the stock of which is owned exclusively by Robert C. Manville, William W. Manville and George H. Manville. In designing and placing on the market a machine as shown by the cut, the Manville Brothers Company had in view and are building a strictly up-to-date, first-class machine, embodying all the improvements that twenty years' experience has brought about. The material used in their construction is the best. The shafts are steel, and extra large. The gears are cut from the solid metal. Working parts of the cams and rolls are tool steel, and hardened. All sliding surfaces are carefully scraped to a fit. These machines are made in several sizes, and have a capacity of handling wire, approximately, from .010 to .375, and from 1 inch to 14 inches in length. This machine has four slides, to which tools are attached, movable towards and from a central suspended form, and are actuated by cams on the shafts, the form and tools being the shape of the article required.

There are some classes of work that do not require a four-slide machine. To supply the demand they are building machines with one, two or three slides, as the nature of the article to be produced demands. Once the wire is started into one of these machines it is entirely automatic, as it straightens, cuts off, forms and ejects the finished piece.

The cut illustrates a few wires that have been formed on these machines.



AUTOMATIC WIRE FORMING MACHINE

It will be noticed that they are shaped in one plane An article with a bend or offset in another direction would require a special attachment, which in many cases would be applied.

The members of the Manville Brothers Company have had twenty years' experience in building machinery for working wire, metal and wood, and the company make a specialty of machinery for producing eyelets, safety and jewelry pins, hooks and eyes, and special articles.

They also manufacture presses, dies and tools.

THE MANVILLE BROS. CO., WATERBURY, CONN.

CARBORUNDUM

ABRASIVES occupy a very important place in the manufacturing world. Every manufactured article is either ground into shape, or is fashioned by a tool that has been ground into shape.

Grinding is the foundation—the basic principle of manufacturing economy. And yet it is a matter that frequently receives but little attention. The cost of grinding materials is small, as compared with other shop expenditures, and actual first cost is too often all that is taken into consideration.

The saving in the cost of labor, the increased production and the superior finish produced by a thoroughly high-class abrasive is lost sight of, and the loss to the shop is very many times the actual cost of the grinding materials themselves.

THE HOME OF CARBORUNDUM

Carborundum within the last few years has taken first rank in the field of abrasives. It is the hardest of all abrasive materials. It is very sharp and brittle. And these three attributes—hardness, sharpness, brittleness—are the characteristics of the ideal abrasive.

The hardness gives it long life; the sharpness gives it rapidity; the brittleness prevents it from wearing smooth and gummy—keeps it always fresh and in condition for fast cutting.

It is made into the form of grinding wheels for every purpose, from the truing of a car wheel to the polishing of a diamond. It is also made into hones and sharpening stones of all kinds for use in the shop and home; into paper and cloth for use in boot and shoe making, and into powders and grains for polishing granite and marble.

CARBORUNDUM

WHAT IT IS

Carborundum is a material made from a mixture of coke, sand and salt, fused in the tremendous heat of an electric furnace. On cooling, the substance thus produced takes the form of crystals of great brilliancy and exceeding hardness and sharpness.

The name Carborundum is formed from "carbon," which enters largely into its chemical composition, and "corundum," the abrasive characteristics of which are surpassed by carborundum.

Carborundum is, with the possible exception of the diamond, the hardest substance known.

It is the nearest approach to the diamond that was ever produced. Literally it is the diamond in commercial form.

Carborundum is made at Niagara Falls, N. Y., in the largest electrical furnace in the world—at a heat that has never been measured. The power to produce this tremendous heat comes direct from the rushing waters of earth's mightiest cataract.

HOW IT CAME TO BE

CARBORUNDUM FURNACE BURNING

A little more than ten years ago Mr. E. G. Acheson, in making some experiments with an electric furnace, produced a little bunch of bright, diamond like crystals. In appearance they were rough diamonds; chemically, they were almost an exact counterpart of that most costly of stones. Scientists smiled when they saw the new substance. It was merely another case of attempting the impossible. It wasn't the real diamond, even though it was near it. According to scientific ideas it had very little value, but practical eyes looked upon it in a different light.

It was very hard and sharp and brittle. As an abrasive it might have considerable value. Developments along this line were commenced. The first furnace that was built had a capacity of a quarter of a pound a day. The first sale was a little shipment of twenty carats to a diamond polisher, at twenty-five cents a carat—a rate of $450 a pound.

This was the beginning. As soon as the marvelous possibilities of carborundum began to be realized the development was rapid.

In 1894 the production of carborundum was 52,191 pounds, and the selling price was but a fraction of the original figure. The new material was commencing to make itself felt in the abrasive world.

In 1895 the works at Niagara Falls were built, and in 1896 the production had grown to 1,207,819 pounds. Last year the output of the factory was 3,838,250 pounds, and this year's production will exceed that figure by a large percentage.

Carborundum is now used wherever an abrasive is required. Its popularity has extended beyond the shores of America, and it is to be found to-day in the most prominent shops the world over.

CARBORUNDUM SPECIALTIES

Carborundum still sells for a little more than other abrasives, but it does so much more work in a day, works so many more days before wearing out, and finishes its work so much better that it is by far the most economical of all abrasives in the end. It is guaranteed to save money to its users.

ECONOMY IN GRINDING

So much for what carborundum is, and where it comes from. Now a word as to what constitutes economy in an abrasive.

The life of an abrasive wheel is not measured by the number of months it lasts, but by the amount of work it does before wearing out.

The efficiency of an abrasive wheel is measured not so much by the amount of work it does during its life as by the amount of work it does in a given time, for this reason: the wages of the man who operates it amount to more than the cost of the wheel itself.

The economical value of an abrasive wheel, then, consists in a well balanced combination of these two essentials—long life and rapidity. Add to these clean work, ease in operating and safety, and we have grinding economy in its truest sense.

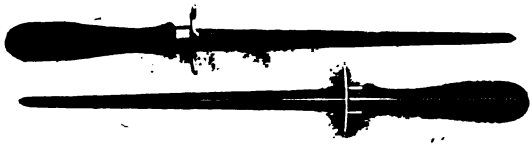
Carborundum meets these requirements more perfectly than any other abrasive that was ever discovered.

CARBORUNDUM SHARPENING STONES

CARBORUNDUM WHEELS

The most general application of carborundum as an abrasive is in the form of grinding wheels. Taking what may be described as simple wheels—that is, those which are nothing more than circular discs with a hole in the centre—the number that may be called for is very large.

In the list given in the Carborundum Company's catalogue we find that the diameters vary from one inch to thirty-six inches, the thickness from one-quarter to eight or more inches. The grits, or sizes of crystals, are more than twenty in number, and the grade scale, which gives the different degrees of hardness of the binding material, consists of nineteen points. With this data at hand it is easy to figure out that something like 80,000 different wheels may be called for.



CARBORUNDUM KNIFE-SHARPENERS

Besides this there is an enormous number of special wheels for dental and fine jewelry work; cylinder wheels, cup wheels, roll grinding wheels, special wheels for grinding machinery, saw gummers, molding wheels, etc.—wheels of every shape and size and grade that could possibly be demanded in abrasive work.

CARBORUNDUM SPECIALTIES

Besides the wheels there are many other forms in which carborundum is used. In the shop we find sharpening stones for the mechanic, the carpenter, the artisan; in the home, knife sharpeners, razor hones, etc; on the farm, scythe stones and axe stones. Carborundum sharpeners find a friend in every user of edged tools.

Next in importance to the sharpening stones come carborundum paper and cloth, largely used in commutator polishing, shoe buffing, etc. In commutator polishing carborundum paper is a distinct success. It is a non-conductor, and so hard and sharp that one sheet does the work of ten to twenty sheets of sandpaper, and at the same time does it much cleaner and better. Sandpaper rides over the high spots. Carborundum cuts them off. Commutator polishing is one of the new uses to which carborundum has been put, and it has proven so decidedly successful that it deserves more than passing notice.

USEFUL IN SHOP AND HOME

Next in line after paper and cloth come carborundum grains and powders, used largely in the grinding and polishing of granite and marble. The grains are graded according to the screens through which they pass, the range of the sieves being 6 to 220 threads to the inch. The powders come in three grades—F, FF and FFF—the latter being the very finest dust that it is possible to make.

COST IS RELATIVE

One of the first questions a person unfamiliar with carborundum is apt to ask is, "How much cheaper is it than other abrasives?" And sometimes on being told that it is not cheaper at all, but considerably higher priced, he waits for no more. It costs more than the old-time grinder—and that settles it.

But cost is relative. If one is buying simply quantity, then the price per piece, or per pound, is the essential point. If one is buying service, then the amount and quality of labor performed per dollar of cost is the essential.

Measured on the latter basis, carborundum is by far the cheapest of all abrasives.

There are three reasons for this. As compared with other abrasives, carborundum does more work. It does faster work. It does better work.

CARBORUNDUM

A few of the results of observations of experienced men in the use of abrasives will be of interest, as giving us data from which to draw conclusions as to the relative value of carborundum and other abrasive materials.

Watchmakers have found that carborundum may be used in place of diamond, as it does the work equally well, and, of course, is much cheaper. Emery and corundum are quite unsuitable for this class of work.

In finishing the soles of shoes, garnet or emery, mounted on cloth or paper, is used. Numerous tests have been made by shoe manufacturers on the use of carborundum in this work, and they state that it does, approximately, six times the work of emery or garnet, does the work faster, and puts on a better finish.

In the manufacture of pottery and porcelain, blocks of carborundum are used for smoothing up the "biscuit ware," emery and corundum blocks having proved very unsatisfactory for this purpose.

CARBORUNDUM FURNACE AFTER BURNING

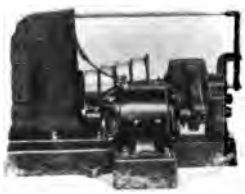
In the manufacture of bath tubs, rubbing blocks of emery have been used. In this class of work it is found that a man can do as much work with a carborundum block in one hour as he could do with an emery brick in one day.

Roll grinders record some very interesting observations of the work done by carborundum wheels. Thus, it is found by one firm that emery wheels would grind about 65 rolls each before wearing down so much as to be useless, while carborundum wheels would grind 220 rolls each. Another roll grinder who purchased a carborundum wheel stated, when it had ground fourteen rolls, that it had "already beaten emery." When he next reported he stated that the same wheel had ground 128 rolls and was "good for five or six more." The difference in the number of rolls ground in these cases was due to the difference in their size.

Many more results obtained from carborundum wheels might be given, but those already mentioned are sufficient to show the superiority of carborundum over the other well-known abrasive materials.

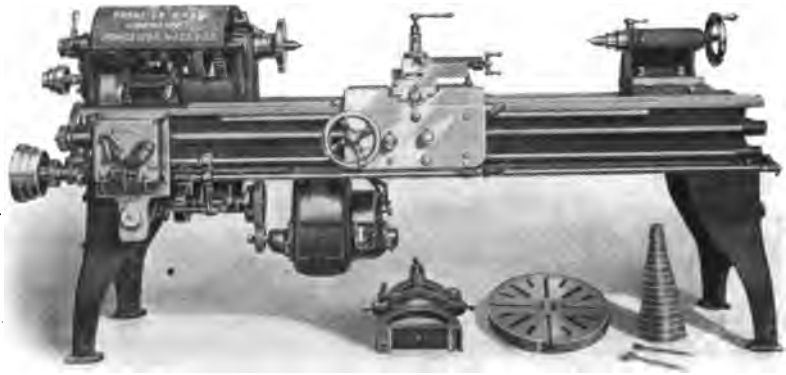
THE CARBORUNDUM CO., NIAGARA FALLS, N. Y.

DRILLING MACHINES



TWENTY-EIGHT years in business. Originators of the present form of vertical drilling machines. Added engine lathes to line in 1880. Total number of machines produced from inception exceeds 31,000. Foremost in improvements, new designs, new features of utility, methods of manufacture, to insure good quality and accuracy. To-day work nearly all done by duplication or interchangeable process. Grinding of all round parts to obtain abso'utely correct round pieces for spindle shafts and for parts whereon are driven or fitted other parts which have standard reamed holes. Scraping flat surfaces, either those that are exposed to the eye or all covered, all with the idea and intention of having accurately fitted bear ngs.

The line of drilling machines includes the well-known form of vertical machines, from one weighing 225 pounds for drilling to the centre of a 13-inch circle to one weighing 10,000 pounds for drilling to the centre of a 50-inch circ'e. Radial drilling machines, from one of 2700 pounds in weight to one weighing 18 tons. Universal radial drilling machine, gang drills, multi-spindle drills, suspension, post and portable drilling machines. Special machines for drilling shells of boilers after they have been rolled to shape. Drilling machines, especially for builders of bridges, structural iron workers, locomotive and car work, shipbuilders' drilling and countersinking machines.



LATHE WITH DIRECT CONNECTED MOTOR

The claim made by the company to be the builders of the greatest line of drilling machines of any concern in the world is well founded.

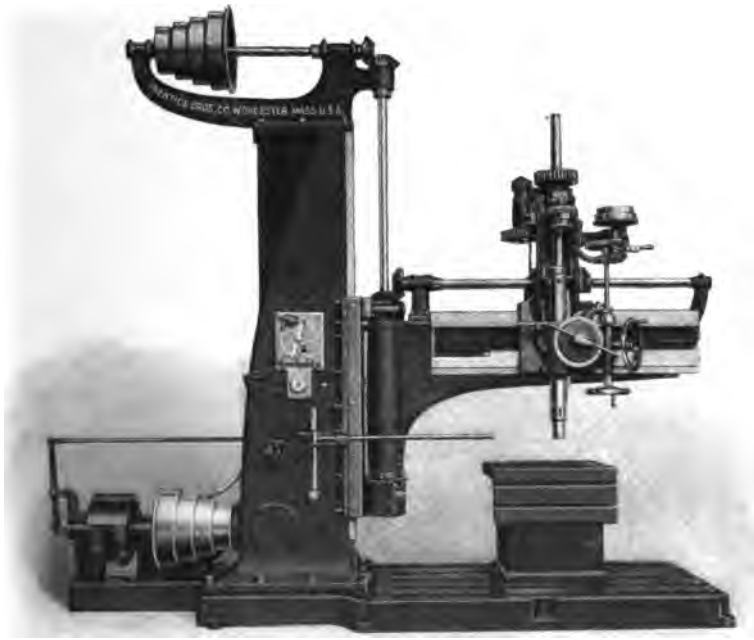
Their lathes, from 12 to 36-inch swing, comprise all the various styles of rest, with or without taper attachment. Plain turning lathes for stud and bolt work, special forming lathes for gun work, and swivel top lathes for taper turning.

The output averages 120 drilling machines and 50 lathes per month.

Without at all vacating the position long held as the foremost manufacturers of belt-driven machines, the company have devoted much attention to the best manner of equipping their drilling machines and lathes with electric motors, and in consequence they are to-day putting out the most advanced practical types of

such machines. Rigid inspection of all machines. None passed except they are shown to be within .0015" of accuracy. Records of all are kept.

General claims made in favor of electrically-driven tools. No power consumed when not in use. No wear of overhead works, belts or clutches. No waste of time in relacing and taking up belts. Clear overhead room; unbroken light. No overhead works or dripping oil. Ease of handling. No belt shifter. Machines placed anywhere about the shop, without regard for main line. No expense for putting up overhead works, and no pulleys on shafting. No long line of shafting with its great weight of pulleys to be whirled around every moment the engine is in motion. The company make especial claims for their own method of motor



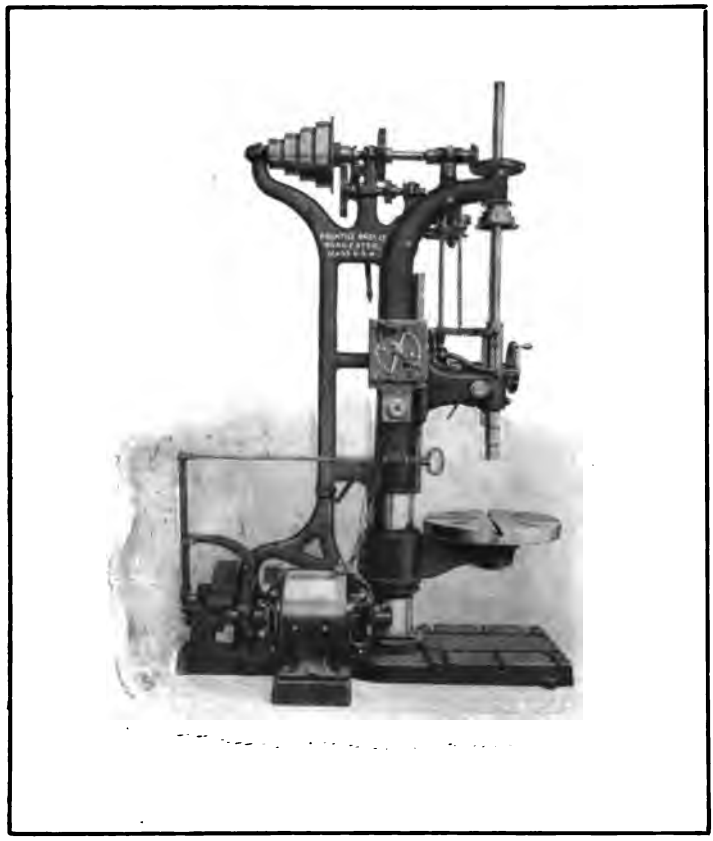
RADIAL DRILL WITH DIRECT CONNECTED MOTOR

equipment. Increased output, particularly of engine lathes, whereon they apply motors and connect with gears that are more than ample to transmit power, which the best of cutting tools can withstand. Minimum cost of equipment, for as the company employ mechanical means entirely for the starting, stopping, reversing and changing speed of work spindle while the motor runs at a constant speed, a small motor only is required.

Cost of operation less, for there is no loss of electrical force which occurs when resistance in field or armature of motors is used to vary speeds. The company's method of changing speeds gives always the known speeds that are wanted. Compactness of machines and electrical outfit. Complete control of machine by starting lever. Screws can be cut to a shoulder, holes tapped to a certain depth, and the motion instantly changed and the tap "backed out" at a faster speed.

Lately introduced and now applied to all power feed drilling machines, a feed mechanism that is controlled by one lever, by which the spindle is quickly approached or returned to or from the work. In this mechanism there are no clutch teeth requiring intermesh to connect power feed, therefore the drill point

can be brought to direct contact with the work, and, with a slight movement of the lever, which has already been used in bringing the drill point to the work, the power feed is instantly thrown in. In common practice time is lost to the operator, for it frequently occurs that the drill point, when in contact with the work, is not in a position that will allow the clutch gears to intermesh, and consequently the spindle is raised to allow the intermesh of gears. Then follows a hand feeding of the spindle until the drill point is brought to the work. With the new mechanism this is entirely saved. The advantages of this will be readily seen.



VERTICAL DRILL WITH DIRECT CONNECTED MOTOR

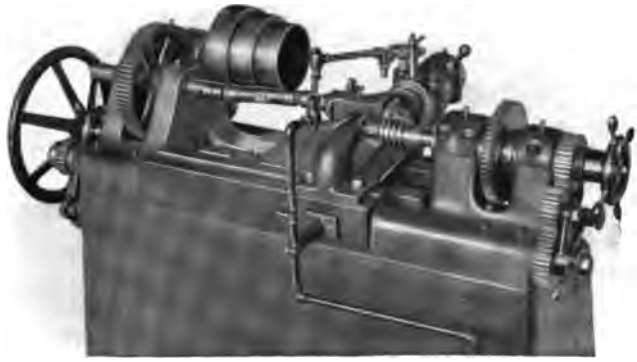
A stop motion for the feed is also part of this mechanism, having in place of the ordinary toothed clutch a roller clutch which allows an entirely novel result to be obtained—one that saves much time in operating the machine. This roller clutch serves as a ratchet, permitting feeding the spindle by hand while the power feed is engaged and "*ahead*" *of it*, so that in starting to drill a hole the operator *can urge or hasten* the feeding of the V point of the twist drill, and immediately that the lips of the drill take the full cut he can, by releasing his grasp on the hand wheel, allow the power feed to control and complete the operation.

PRENTICE BROS. CO., WORCESTER, MASS.

AN ECONOMICAL TOOL

HAS the reader ever considered what it costs to chase thread on worms in lathe? If he has not, it would be well worth giving serious consideration, that is, in comparing the output of our worm milling machine against the output of the lathe. This worm milling machine is designed to mill worms, taps, of any pitch, either single, double, triple or quadruple threads, either right or left hand, and its capacity is 4 inches in diameter by 6 inches long. It is well known that milling is the quickest and therefore the most economical method of removing metal, and if there is any question as to the truth of the above statement, the machine here described proves it beyond a doubt by milling worms five to ten times cheaper than what it can be done in a lathe, exact duplicates of one another.

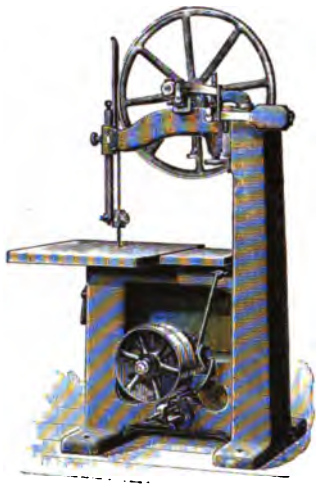
The screw is driven through gearing from the main spindle which carries the worm blank; thus the cutter and blank are always held in proper relation, regardless of pitch of screw or worm to be cut, making it impossible to lose the thread should the cutter be drawn out of work for any reason. The advantage of this point can be made plain by considering the other methods of cutting worms. The cutter resembles an ordinary rack cutter, and there are a great many cases where the same cutter is correct for different threads where at first it would not be apparent; for instance, a cutter for ¼ inch lead single thread is correct also for ½ inch lead double or 1 inch lead quadruple, etc., the actual size of thread being the same in all. The cutter may be adjusted in or out without disturbing the angle adjustment. A continuous stream of oil flows on cutter and keeps the cutting edge flooded. The movements are identical for triple, quadruple, etc., threads. All adjustments can be made in a few seconds by an inexperienced person. All end thrusts are taken on ball bearings, and all running bearings are bushed.



CLEVELAND AUTOMATIC MACHINE COMPANY, CLEVELAND, OHIO

PATENT WOODWORKING MACHINERY

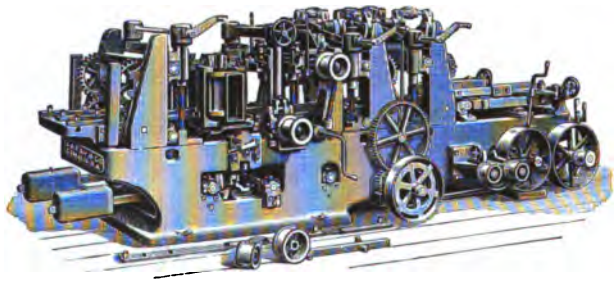
IT would be no easy task to select from the hundreds of industries that particular one which will best illustrate the world's progress in the line of mechanical art and invention. If we should, however, choose that of woodworking machin-



NO. 50 BAND SCROLL SAW. PATENTED FEBRUARY 27, 1900

NO 8 VERTICAL CUT-OFF SAW AND GAINER

ery, we would not be far astray; and if we were well informed of the history of that industry, we would inevitably settle upon one certain concern in the United States as an illustration, for the reason that, with this concern, the construction of

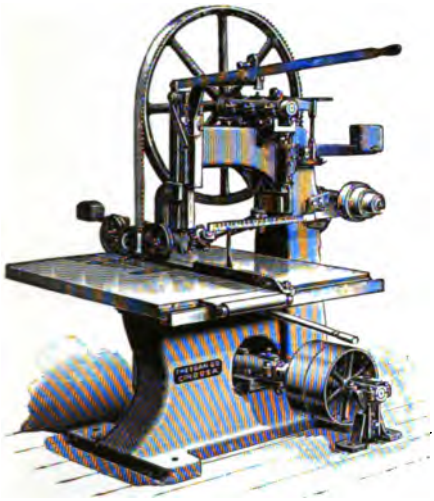


NO. 26 HEAVY DOUBLE CYLINDER PLANING, MATCHING AND JOINTING MACHINE PATENTED JAN. 9, 1900, MARCH 20, 1900

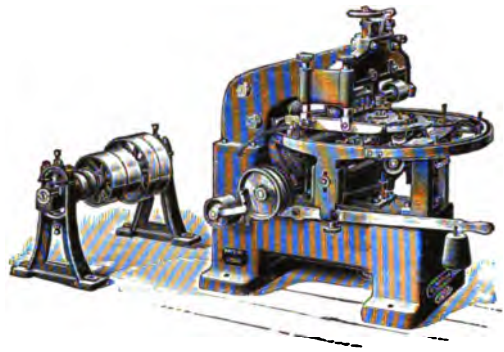
woodworking machinery first began in this world; and, by this company, this class of machinery has been brought to the highest degree of variety and perfection.

This concern is known as the J. A. Fay & Egan Company, of Cincinnati, Ohio. During the past year this company has taken out nearly two hundred

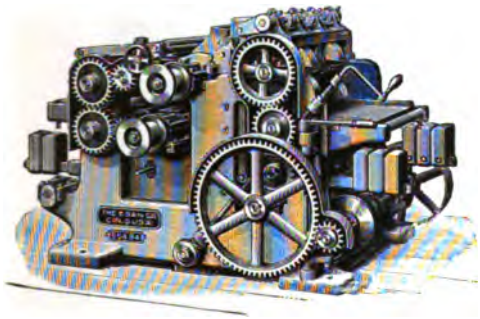
patents, embracing all the latest improvements in woodworking machinery. Here are a number of the latest machines which this company has gotten out: No. 1 self-feed band ripping saw, fixed knife planer, No. 18 double cylinder surface planer, No. 50 band scroll saw, automatic spoke facer, No. 8 vertical cutting-off saw, new triple drum sander. Heavy planer, matcher and jointer, and many other improved machines.



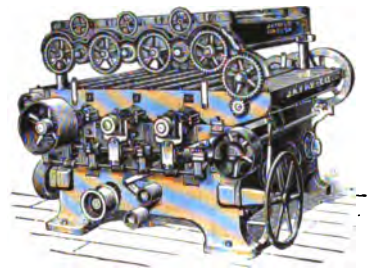
NO. 1 SELF-FEED BAND RIP SAW.
PATENTED FEB. 27, 1900. OCT. 2, 1900



NO. 51 AUTOMATIC ROTARY SPOKE FACING MACHINE.
PATENTED JUNE 25, 1901



NO 18 DOUBLE CYLINDER PLANER.
PATENTED DEC. 19, 1899, FEB. 6, 1900



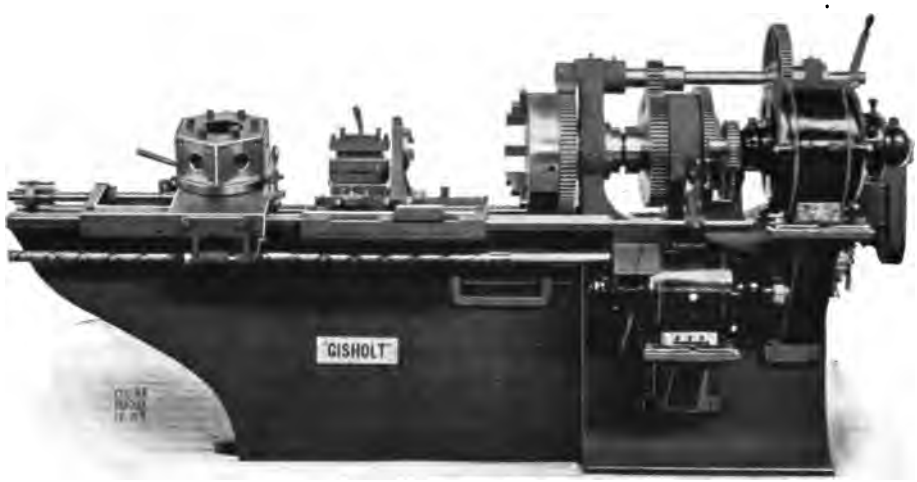
NO. 4 TRIPLE DRUM, EIGHT ROLL, POWER FEED SANDER. PATENTED MARCH 20, 1900

Engineers and others desiring blue-prints of the most modern, up-to-date plants for car shops, railroad repair shops, saw and planing mills, furniture, desk and chair factories, and general machinery for working and cutting wood, can get full information by addressing J. A. Fay & Egan Company, manufacturers of woodworking machinery, 226-246 W. Front Street, Cincinnati, Ohio.

ABOUT THE WELL-KNOWN GISHOLT LATHES.

TO DAY they are the standard machines for chucked work. Continued duplicating of orders from well-pleased purchasers proves this. And the orders came, too, from among those manufacturers of machine tools, locomotives, engines, pumps, motors, printing presses, cranes, elevators, valves, paper and textile machinery, automobiles, transmission machinery and mining machinery whose reputations for *accurate* and *high-grade* work would compel them to condemn, in no uncertain terms, that machine which should be tried and found not equal to their requirements.

Gisholt lathes were at first accorded only the doubting and derision of the manufacturers above referred to. But this lathe, the outlines of which are now of common knowledge, was built to withstand a long, up-hill fight for that recognition which is given so grudgingly to whatsoever sets at naught time-honored, time-taking practices.



GISHOLT LATHE ELECTRICALLY DRIVEN BY A VARIABLE SPEED MOTOR, BUT WITH SMALL CONSTANT SPEED MOTOR OPERATING THE DEVICE FOR MOVING THE TURRET RAPIDLY BACK AND FORTH

Now that over fifteen hundred Gisholt lathes are in successful, every-day operation the world over, the fight seems well in hand. Foes have turned to friends. There are still those, however, who, through lack of time or opportunity, have, perhaps, not yet fully satisfied themselves of the capabilities of this most excellent and serviceable machine. And to these a word:

Gisholt lathes are built on massive lines, the bed, headstock and brackets being cast all in one piece, a necessary and effective precaution against the twisting and vibratory strains resulting where wide shaving tools, or several tools cutting at once, are used. The heavy hexagonal turret and the four-tool turret tool post, which may, on many pieces, be simultaneously brought into action, carry these broad shaving tools and multiple cutters above alluded to, while with either the turret, which slides directly on the ways, or the turret tool post, which rests

on the carriage, threads may be cut, including all United States standard pitches from 4 to 56, while metric lead screw and change gears are furnished if desired. Boring and turning at the same time, which has become common practice since the advent of the Gisholt lathe, was one of the things that was scoffed at not so very long ago—only another proof that "the world do move."

Our aim is to also "move" and to keep pace with the more and more exacting requirements of those who now do not feel so skeptical towards the machine that has in many instances put thousands of dollars into their vaults.

If you are duplicating parts that require to be bored, turned and faced, and perhaps tapped, and are doing it in the way that obtained before the Gisholt appeared and wrought its wonders, you are not doing justice to a fine opportunity, which lies in the privilege you have of putting in one of these famous lathes on our positive guaranty. You give us the necessary information about your pieces; then we say that same can be finished in stated times on a properly equipped Gisholt.

If "Barkis is willin'," we then, in his own shop, demonstrate that our lathe is "up to" our guaranty. If success fails to crown our efforts, "Barkis" is nothing out; the expense is all ours.

If, in fairness, more can be desired, suggestions will be gladly considered.

Gisholt lathes are also easily adapted to the finishing of work off the bar, such as large pins, studs, bolts, etc., and wherever installed for this class of work have more than fulfilled the expectations of their purchasers; and, further, the capacity of the machines for chucked work is not altered in the slightest, a point that should not be overlooked. Then, again, our guaranty, with which you are now acquainted, is also broad enough to take in this class of work just referred to.

Our catalogue will give some specifications, dimensions and illustrations of the five swings in which this lathe is built. Also, it shows a few of the *five thousand* and more pieces that have been finished with our specially designed tools. The experience thus gained is at the service of those who have neither time nor facilities to furnish their own tools. Write about your needs to us or to any of our agents, who are the following:

W. H. Foster, 126 Liberty street, New York, and Bourse building, Philadelphia; Henshaw-Bulkley & Co., Fremont and Mission streets, San Francisco; C. W. Burton-Griffiths & Co., London, Eng.; Fenwick Frères & Co., Paris, France; Schuchardt & Schütte, Berlin, Cologne, Vienna, Stockholm and St. Petersburg.

GISHOLT MACHINE COMPANY, Madison, Wis., U. S. A.

VARIABLE SPEED CONTROL

ONE of the first questions that arises in designing and in the use of any piece of mechanism is, how may the speed be changed as conditions vary? There have been numerous attempts made to solve this problem, but in practically every case the devices designed have failed to make a complete solution of the problem because they have been found faulty in one or both of the following respects: First, it has been found impossible to get a fine gradation of speed without an undue amount of complication and expense. Second, in such devices as have the necessary gradations their form of construction has been so cumbersome that their field of application has been comparatively limited.

In the Speed Controller manufactured by the Consolidated Machine Specialty Co. we have a device that will give an absolutely complete gradation in speed, and one of such simple and compact form that it can be applied to any machine on which it is desirable to obtain a change in speed.

Of course, the simplest method of obtaining variable speed on any class of machinery is to drive by a variable speed countershaft. There are several forms of such countershafts on the market, but the speed controller we manufacture is much more compact and practical than any of the others. Furthermore, its general design is such that it can be readily used either as a countershaft, a floor stand, or it can be directly attached to virtually any class of machinery.

DOUBLE CONTROLLER

In order to convey an idea of the wide range of adaptability of our controller, herewith are given some of the very varied ways in which it has been or may be applied.

First, printing presses of all sorts and descriptions, varying from the small job press up to the large stop cylinder press.

Second, embossing presses where it is necessary to vary the speed, depending upon the grade of stock to be handled.

Third, lathes, drills, milling machines, planers, and, in fact, all forms of machine tools.

Fourth, laundry machinery, especially mangles and shirt machines.

Fifth, all forms of winding machines where it is desirable to change automatically the speed of the reel as it increases in size.

Sixth, rubber calendering machines.

Seventh, textile machines.

Eighth, power sewing machines.

Ninth, automatic screw machines.

Tenth, drying cans where it is necessary to change the speed for the different weights of goods.

Eleventh, cam cutting machines.

Twelfth, alternating current motors upon which it is not possible to obtain a speed variation, and which are in great demand for individual drives.

Thirteenth, paper machinery.

These are some of the uses to which our controller may be put in the direct connected form, but it will serve the purposes equally well in the floor stand form or in the countershaft form, especially where the apparatus to be used is already in place.

The principle on which these controllers operate is as follows: There are discs with their opposed faces made in the form of an annular groove. Between these discs friction rollers are mounted, the radii of these rollers being the same as the radius of the curvature of the annular grooves in the discs These friction rolls are mounted in such a way that they may be swung simultaneously about their points of support and thus made to take positions at various angles to the shaft or axis of the controller. If these rolls are so set that they are parallel with the shaft of the controller, they are making contact with the discs at points equidistant from the shaft; therefore the speed of the two discs will be the same, as one drives the other by means of the friction rolls.

We call the disc driven by the prime mover the driven disc, and the other—the disc which drives the machine—we call the driving disc. If the position of the rolls be changed so that they make contact near the hub of the driven disc and on the outer edge of the driving disc, the speed of the driver will be much less than that of the driven, since the driving is from a small to a large diameter. If, on the other hand, the position of the rolls be reversed so that they make contact near the outer edge of the driven and close to the hub of the driver, the speed of the driver will be much greater than that of the driven, as the driving in this case is from a large to a small diameter. As it is possible to get the two extreme limits of speed, it is readily evident that any intermediate speed can be obtained. The gradation is absolutely complete, the amount of gradation being dependent on the form of the controller.

There is virtually no limit to the size of these controllers. The smallest size we ordinarily build generates 1-10 H. P., and gives ranges in speed from 130 revolutions per minute to 900 revolutions per minute on the driving disc, with a constant speed of 350 revolutions per minute on the driven disc. A 60-H. P. controller we built for the Hood Rubber Co., of East Watertown, Mass., gives ranges in speed from 58 revolutions per minute to 365 revolutions per minute, with a constant speed of 150 revolutions per minute.

Our ordinary speed ratio is 7 to 1. In some sizes the ratio is still greater, but in practically all cases with which we have been brought in contact the ratio of 7 to 1 is amply sufficient.

Since this machine was first put on the market it has been improved greatly, and we will warrant the workmanship to be first-class in every respect.

CONSOLIDATED MACHINE SPECIALTY CO., BOSTON, MASS.

VAN NORMAN DUPLEX MILLING MACHINES

THE Waltham Watch Tool Company, of Springfield, Mass., makers of the Van Norman duplex milling machines, are now putting on the market full universal centres to be used in connection with the Nos. 1 and 2 sizes of these machines, which will adapt them for all the requirements of the standard types of universal milling machines. The Van Norman machines differ from the other types on the market in having the cutter head adapted to be set and operated at any angle. This cutter head is mounted on the side of a heavy moveable ram, which can be carried in or out over the table of the machine to bring the cutter into the most convenient position for operating, and the arrangement of the head is such that cuts at any angle can be carried through the full longitudinal movement of the table.

NO. 2 MACHINE. WEIGHT 2,300 LBS.

The two principal types of milling machines on the market, those with horizontal or with vertical spindles, each have their particular points of advantage, those with vertical spindles being best adapted for surfacing with end or face mills, while the machines with horizontal spindles are more generally used in disc milling and other purposes.

The Van Norman duplex machines will perform the work of both these types, and are equally serviceable for milling at angles.

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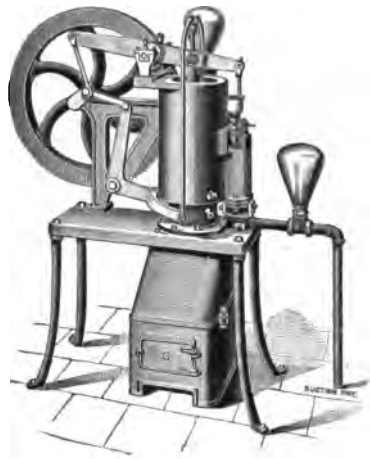

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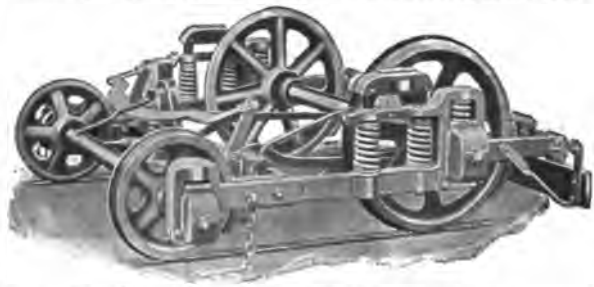

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CASSIER'S MAGAZINE

VOL. XXIII NOVEMBER, 1902 No. 1

COMPRESSED AIR IN THE MACHINE SHOP AND FOUNDRY

By William L. Saunders

A PNEUMATIC CHIPPING HAMMER

AN industry like that of compressed air, which has recently made such strides in its useful applications, may be studied with interest from time to time with something new always available. In the notes that follow, an effort has been made to put together such data on the subject as may be useful to a general manager of a manufacturing company, in ascertaining whether pneumatic appliances which have reached the successful stage are suitable to meet the conditions which exist in his case, and what will be the approximate cost of installation, operation, and maintenance. He may also gain some hint as to whether or not it will pay to invest money in a compressed air plant.

Compressed air and electricity are broad and new fields for industrial research; hence, we will always find failures in the field of experiment, and in the literature on the subject we too often see ideas set forth which are really nothing more than theories, dangerous in themselves, because, being presented to the public in a plausible manner, persons are apt to invest money in them only to find that before reaching the point of usefulness an experimental period and further expenditure of money have to be encountered.

Electricity, having advanced beyond compressed air in its industrial march, appeals to the investor with greater confidence, because of the numberless cases where it has paid to use it. With compressed air there have been too many unreliable experimenters and writers, and both confidence and money have, therefore, been lost.

A single branch of the subject has been selected for treatment here,—the use of compressed air apparatus in the machine shop and foundry,—and the writer would say at the outset that he does not by any means advocate the adoption of every pneumatic device that is offered. Many of them, in fact, are to be avoided quite as carefully as perpetual motion and other kindred schemes; but there is a wide range through which compressed air appliances will work marked economies.

There are some pneumatic devices

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FIG. 1.—A SAND BLAST TUMBLE BARREL.

whose action is certain and whose limitations are fully known and well-defined, and in adhering to these the shop manager will find means to improve works output and decrease the labour involved in its production.

Taking the matter up logically, let us examine the elements essential to a plant using such standard forms! First we must have the equipment consistently planned after a study of the conditions. Generally speaking, it is best to have the air compressor installed in a central position convenient to boilers and cooling water and where the existing engineering force can take care of it. From this point air pipes are run to the several departments where air is to be used.

Some idea should be formed of the amount of apparatus to be installed for present wants, the quantity of air it will require, and the location of this apparatus. An allowance should then be made for a natural growth. These data will enable the air mains to be properly proportioned and a compressor, or compressors, selected to give the best results.

In a foundry from one to several sand sifters and rammers can be used to advantage in the preparatory work, and sand blasts, sand blast tumble-barrels, pneumatic hammers and chippers,

grinders, and scratch brushes in the cleaning and finishing up of the castings, the extent of the outfit depending upon the size of the individual establishment and the class of work it is turning out, that is, whether small, medium, or large castings are made.

Any attempt to differentiate between the various makes of such apparatus would be out of place at this time. It is sufficient to say that no one maker has the best of everything, and that several have very good forms of these special machines.

The sand blast tumble-barrel, speaking from experience with it, is a great improvement over the old forms. Briefly described, it consists of a tumble-barrel revolved by rollers running on its outside, and the whole is encased in a box with a sliding door. At the centre, where the bearing would be in the old form, is an inclined sand blast jet. As the barrel turns, the castings are tumbled again and again in front of the blast, and every part is exposed to its cleaning effect as if held in front of the jet by hand. The illustration on the opposite page represents one of these barrels and shows some castings both before and after cleaning, giving a fair idea of the character of work done.

A feature of this tumble-barrel is the rapidity with which it cleans the castings, an ordinary charge ranging from twenty to thirty minutes. On account of the small amount of tumbling necessary, fragile castings can be tumbled without risk of rounding edges, bruising, or projections being worn or broken. Useful as has been the dusty old "rattler," this new form is much its superior. For its operation about the same quantity of air is required as for the regular sand blast.

FIG. 3.—A PNEUMATIC SCRATCH BRUSH FOR CLEANING CASTINGS

The usual sand blast, and, in fact, the tumble-barrels, should always be operated in a special room, built at one side or in a corner of the foundry, or, what is better, in a separate building so situated that the dust and grit cannot drift into machinery or through the entire foundry to cause wear to machines and men alike. This "cleaning room," Fig. 6, can be so placed as to avoid any extra handling. But it will be economy to isolate it in any case. The floor should be a grating, and should be connected with an exhaust fan so that dust will be drawn down and carried off into a dust collector.

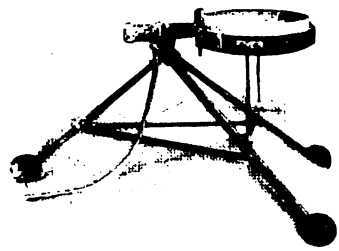


FIG. 2.—A PNEUMATIC SAND SIFTER

It is also necessary that the operator be provided with a helmet with a fresh air supply hose attached to it, because, at best, the atmosphere in the sand blast room is filled with an impalpable dust which would be harmful without the breathing helmet. The dust collector is somewhat like a separator, and generally consists of an enlargement in the pipe into which water is sprayed. The dust is caught by the water and allowed to settle or run off into a drain.

In cleaning out cores and inside spaces the sand blast is indispensable, as it does the work rapidly and far more thoroughly than any other means yet devised. Formerly, with intricate castings, requiring a great deal of core work, one of the difficult parts of the task was to remove the cores from the

FIG. 4.—A PNEUMATIC SAND RAMMER FOR DEEP MOULDS. MADE BY THE PHILADELPHIA PNEUMATIC TOOL CO., PHILADELPHIA, PA., U. S. A.

narrow parts of the castings. Usually this was done by digging and scraping away with chisels and hooks. Now the sand blast is employed, and it has been found that one of these simple adjuncts will accomplish more than formerly could be done by from six to ten cleaners. Not only does it do the work more quickly, but the casting is left in far better condition for the succeeding machining processes, as scales, burned spots and oxide are cut away without injury to the solid metal. For the best work of the sand blast apparatus pressures ranging from ten to thirty pounds per square inch and a volume of about 120 cubic feet of free air per minute are necessary. Air for operating may be obtained from a low-pressure compressor for this purpose alone, or from the receiver between the high and low-pressure cylinders of a compound compressor used for shop purposes in general.

Pneumatic sand sifters may be regarded as somewhat novel, but several forms have been devised which will prove of service, and where compressed air is in use, or where its adoption is under consideration, the use of these is warranted. One form of such sifter, Fig. 2, consists of a suitable frame supporting a cylinder with a piston connected to a frame which it vibrates rapidly, shaking the attached sieve, leaving the moulder free to shovel. These sifters can be fastened to a column or to the wall wherever convenient, or the portable form may be placed close to the work. It is claimed that one man with such a machine can do in one hour as much as he could do in five hours without it. The average air consumption when working is about 12 cubic feet of free air per minute at a pressure of eighty pounds.

Another special device receiving attention in foundries where large work is turned out, or where moderately large pieces are produced in quantity, is the pneumatic sand rammer. Some foundrymen dispute the value of this device, but it unquestionably does remarkable work where the conditions are in any

way favourable. Several forms have been brought out, all more or less bulky and crude; but even these made such good records that the device has been perfected and to-day may be classed as one of the permanent fixtures of an up-to-date foundry engaged in general work of any size. The smallest size of hand rammer made is useful in ramming up flasks, piece ramming on large work, ramming concrete, and similar work. A small valve in the handle puts the machine under perfect control of the operator. Complete, it weighs 20 pounds, and strikes from 250 to 300 pounds, using 11 cubic feet of free air per minute at a pressure of from 60 to 100 pounds. Fig. 5 shows one of these rammers.

A somewhat heavier form of this device weighs 45 pounds. With air at from 50 to 100 pounds pressure it also strikes from 250 to 300 blows per minute and uses 15 cubic feet of free air per minute. It has two handles and removable rammer butts, and makes a good record for moderately heavy ramming on loam or ramming up converter bottoms in steel works, etc.

Another type, Fig. 4, is intended to be worked suspended from some form of crane. It is much heavier and is more powerful than the other forms. The air supply is taken through the upper end of the elevating screw which passes through a block, in turn swivelled to the suspension straps,—an arrangement which allows the freest movement.

Pneumatic moulding machines are known and in daily use in many places, but their value is not fully understood by a large proportion of manufacturers. A typical machine of this class consists of a very substantial table, the standard of which is an inverted air cylinder whose size depends upon the dimension of the work to be done. Over this table is suspended a ramming head or solid back, to the ends of which are attached side rods running down to the base of the machine where they are hinged to allow the ramming head to be swung back to clear the flask. At one side is a three-way controlling valve which admits air to the cylinder or opens the exhaust.

In operation the "flask" is put on the table, filled with sand, the head is swung into position and the valve is turned. The air, under a pressure of 70 to 80 pounds per square inch, then lifts the entire table, with flask, pattern, and sand, up against the head, not with a steady pressure, but forcibly with a blow. Frequently one blow is sufficient, at other times two or three are found necessary, all depending upon

FIG. 5.—A PNEUMATIC SAND RAMMER FOR MEDIUM AND SMALL WORK

FIG. 6. -READY TO SAND-BLAST CASTINGS

the character of the mould. Turning the valve further exhausts the air from the cylinder and allows it to drop. The operator then cuts the sprue holes and turns a thumb-screw to start a pneumatic rapper or vibrator, which frees the pattern from the mould far better than hand rapping. Another lever is then thrown and the flask is stripped or carried free of the pattern. This pneumatic vibrator causes the entire pattern to quiver or shiver in such a way that it is absolutely freed from the sand without enlarging the mould and distorting the shape, thus maintaining the size and effecting a considerable saving in the amount of metal used in the casting.

Following in natural sequence we come to pneumatic chippers for cutting off feathers, risers, sprues and general trimming-up of the rough castings as they leave the sand or the tumble-barrel. Too frequently castings are sent into the machine shop with edges and excrescences which, if removed in the foundry, would save valuable time and reduce the amount of machining necessary, besides reducing the wear and tear on tools and machines alike. Regarding the wisdom of pneumatic chippers for this work there can be no question. These tools are made in different sizes to meet different conditions, but for general foundry trimming a medium size gives the best result.

The number necessary depends entirely upon the class of work: but, generally speaking, there are too few of them rather than too many. There are probably few foundries that could not use from one to five of these handy little cost reducers.

PNEUMATIC HAMMERS

In a general way pneumatic hammers may be divided into two general classes: — Valveless hammers, or those in which

the piston is the hammer, and, in its movement, opens or shuts the inlet and exhaust ports; and valve hammers, or those in which there is a distinct and separate moving valve. The former are invariably short-stroke hammers, and find their greatest field in calking and chipping. Their piston speed is high, from 10,000 to 15,000 strokes per minute being not uncommon.

Valve hammers, on the contrary, are of comparatively slow speed, working at between 1500 and 2000 blows per minute. The travel of the piston or hammer is proportionately longer and the blow heavier in like degree. For this reason hammers of this type, or at least the long-stroke ones, are not so well adapted to chipping, serving a better purpose in riveting work.

The piston diameters of pneumatic hammers range from ¾ inch to 1¾ inches, and the length of stroke from half an inch to 5 inches. The lightest

FIG. 7.—AN AIR HOIST MADE BY THE CURTIS & CO MFG. CO., ST. LOUIS, MO., U. S. A.

hammer weighs about 3 pounds, from which figure the weights run up as high as 26 pounds. Pneumatic hoists of various kinds occupy prominent positions in the foundry. As an example of this form of compressed air apparatus Fig. 10 is of interest, rep-

FIG. 8.—A LIGHT PNEUMATIC HAMMER

resenting a corner of the foundry of the Lidgerwood Manufacturing Company. Three overhead cranes span the spaces occupied by pneumatic moulding machines and enable the heavy flasks to be picked up, placed in the machines, turned over and taken away with the least handling and in a minimum of time. Each of these cranes has a capacity for lifting 2000 pounds to a height of 6 feet. They are set perfectly level, and have bushed bearings so that they will roll at the slightest touch. In the same works is another foundry crane with a span of 48 feet and a capacity of 5000 pounds. The hoisting is done with an air hoist having a 10-foot lift attached to a trolley actuated by hand ropes from the floor. The crane travel is obtained through electricity power, the motor being operated from the floor also by conveniently arranged hand ropes. This is a most convenient crane for general use.

It is claimed that the air hoist will do about half again as much work as any other form of hoist for lifting copes, drawing patterns, and shifting cores. In any case, its slow, steady movement closely resembles hand lifting, and as such hoists are under the most perfect control of the operator, permitting the most delicate handling,—an essential in handling cores and moulds,—they are most useful devices in the foundry. Hoists of this type are made in almost every size, from the smallest to those lifting as much as 10,000 pounds. Generally, they have a lifting speed of from 10 to 36 feet per minute.

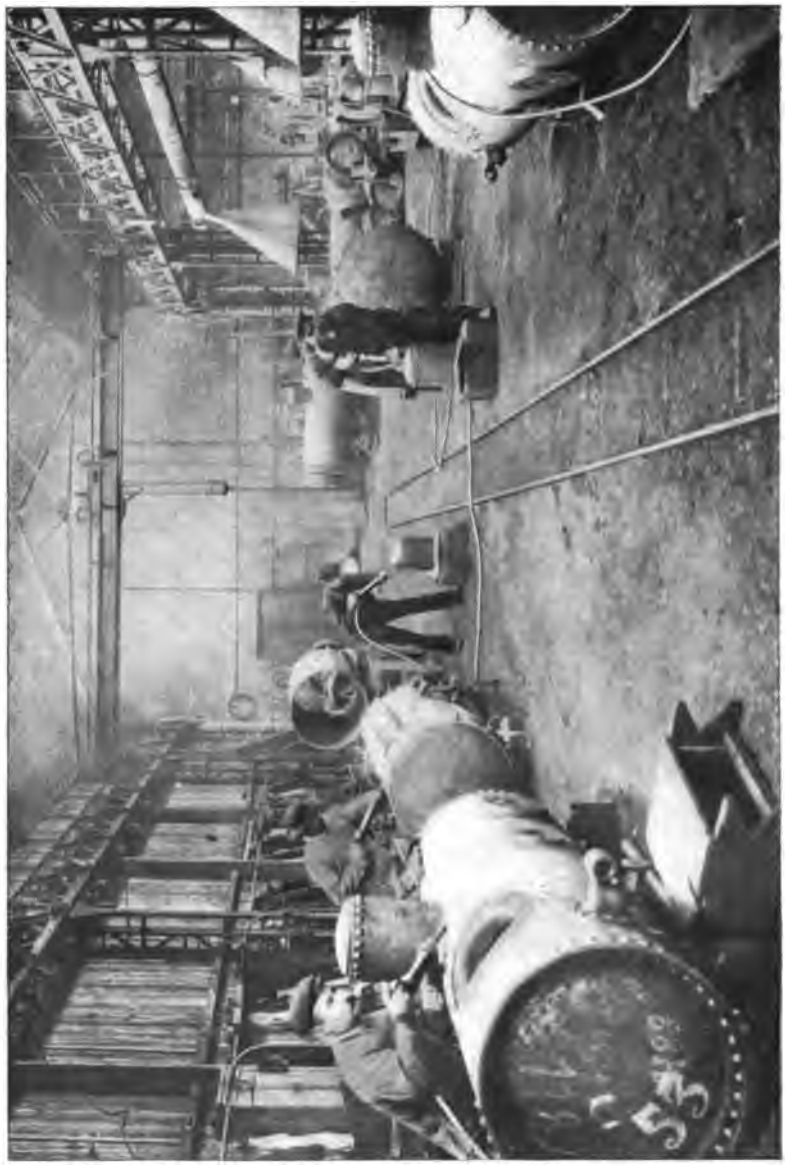


FIG. 9.—PNEUMATIC HAMMERS IN THE BOILER SHOPS OF MM. J. & A. NICLAUSSE, PARIS, FRANCE

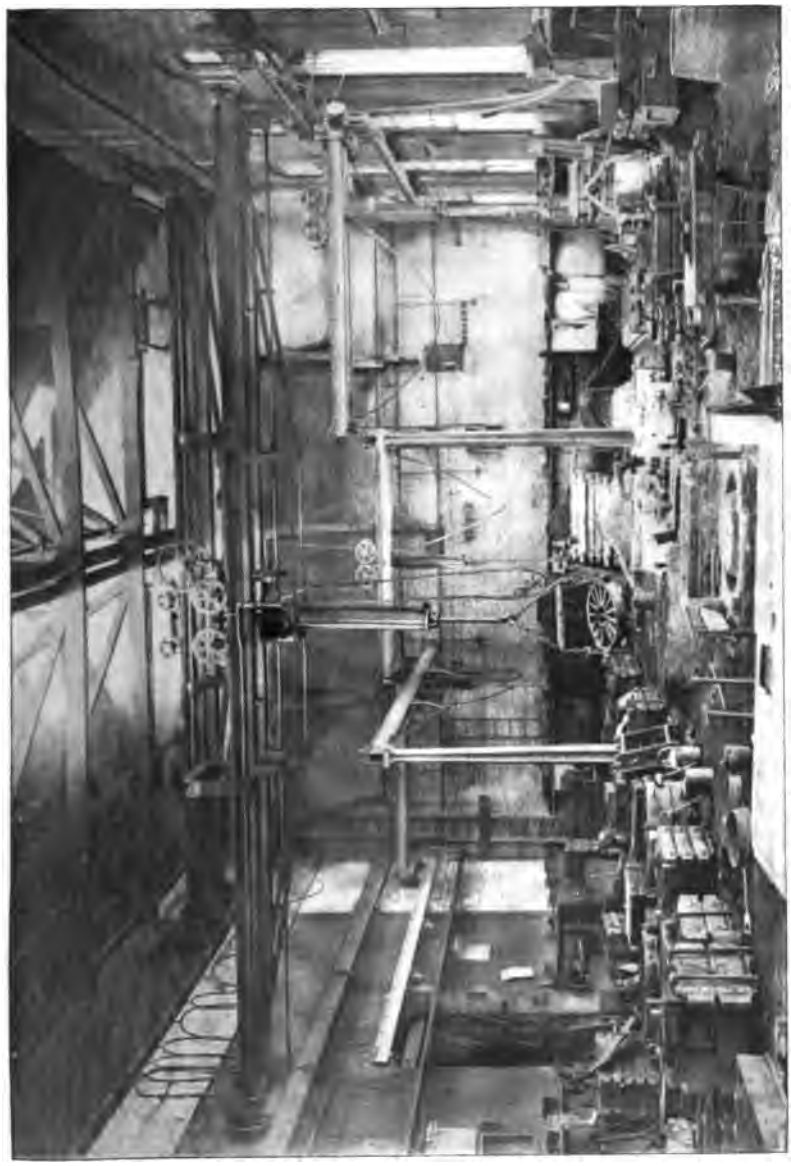


FIG. 10.—PNEUMATIC HOISTS AND CRANE IN THE FOUNDRY OF THE LIDGERWOOD MFG. CO., BROOKLYN, NEW YORK

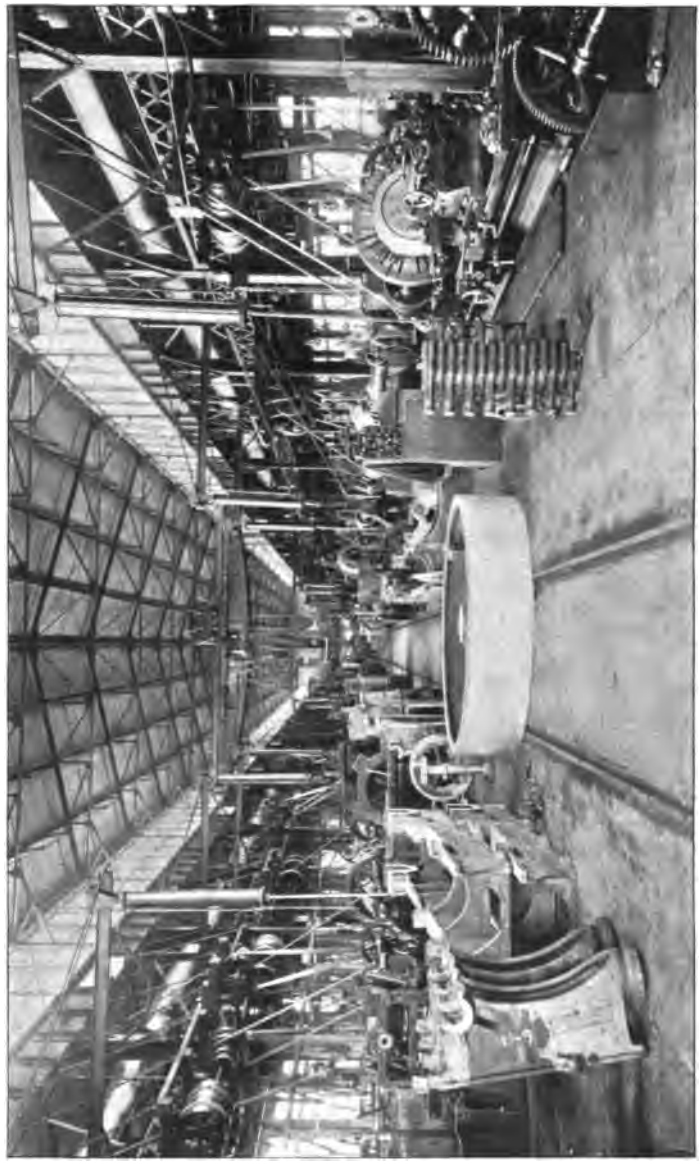


FIG. 11.—PNEUMATIC HOISTS ON SWINGING BOOMS AND A PNEUMATIC TRAVELLING CRANE IN THE SHOPS OF THE INGERSOLL-SERGEANT DRILL CO., AT EASTON, PA., U. S. A.

With the air hoist we may leave the foundry and enter the machine shop, for we now have our castings made, cleaned, and trimmed, ready for the lathe, planer, milling machine or other tool, as the case may be. One crucial factor in the economical administration of a machine shop is first to have as few men as possible involved in any given operation, and, second, to keep every man and every machine busy on productive work every minute of the working day.

The speed of operation of a given machine is fairly well fixed, especially when operating steadily on a certain class of work, making, for instance, the same piece day after day. The number of machines a man can operate is fixed, in some places by physical limitations, in others by the dictates of labour unions. In the former case and where the pieces to be handled are heavy, a means for handling them decreases the idle time of each man and machine, besides lessening the actual physical wear on both operator and tool. The old way of calling an operator from a neighbouring machine when a change of work was to be made, lifting the finished piece out and putting in a rough piece, has passed away forever in progressive works, and now the plan shown in Figs. 11 and 15 must be used if it is desired to keep up with the march of progress. These two illustrations represent two types of air hoists employed in the works of the Ingersoll-Sergeant Drill Company, at Easton, Pa., U. S. A.

Fig. 10 shows the familiar single straight-away lifts, hung from swinging arms and arranged to lift the smaller pieces and swing them over lathes, planers, or other tools. The same picture shows a large travelling crane, also operated by air. This spans the shop and handles the heaviest pieces with ease. Air to operate this crane is supplied by a hose which is suspended from special hangers along the centre of the shops, and loops up or straightens out according to the direction in which the crane moves.

Fig. 15 represents several more compact forms of hoist in which the cylinders are placed horizontally. The piston in each has a rack cut in it which engages a gear on the shaft of the winding drums. This form, as will be seen, is suitable for use in a shop with fairly low ceilings. The illustration represents several of these hoists mounted on iron beams running transversely across the shop over the machines.

The purpose of this form of hoist is very well shown. Castings or other

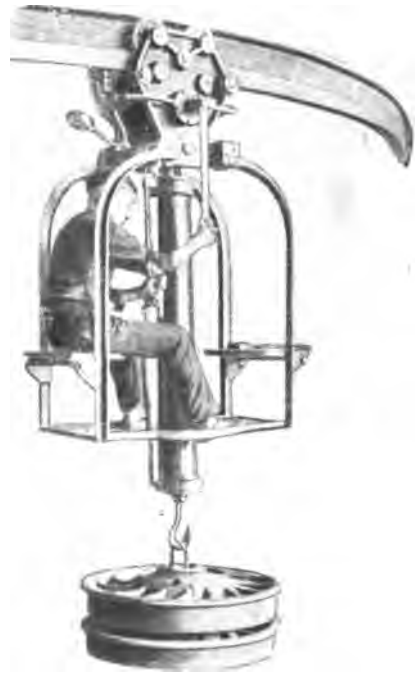


FIG. 12.—A PNEUMATIC OVERHEAD TROLLEY USING THE HALSEY SYSTEM

pieces too heavy for a man to lift are easily picked up from the aisles and carried over to any machine where they are held until properly centered; or the finished pieces are quickly lifted from the lathe and placed on the floor out of the way, without the operator touching them.

In another department of the same works long-cylinder pneumatic hoists are mounted on swinging arms,

FIG. 13.—A PNEUMATIC CHAIN HOIST IN A FORGING SHOP. MADE BY THE EMPIRE ENGINE & MOTOR CO., ORANGEBURG, NEW YORK, U. S. A.

giving them a considerable range. Another type of pneumatic hoist uses a small motor and a differential system of gears, giving it greater lifting power than is possible with the direct lift with the same amount of air. Fig. 13 shows such a hoist, as used in a blacksmith shop to handle steel bars in and about the hammer. This class of work is a severe test under which these machines stand up admirably. Unlike electrical apparatus, dust and grit cannot hurt them beyond increasing the frictional wear.

Fig. 17 shows the application of an air motor to the usual form of crane drum. This consists of a reversible motor, enclosed to protect it from dust and dirt, geared to a winding drum in the same way that an electric motor would be used. This arrangement can be mounted on the boom of a crane and makes a very satisfactory form for yards, or foundry and forging shop cranes. The same motor is often bolted to the cross beams of a travelling crane when a shop travelling crane is desirable. In this case the hose loops up or straightens out as the crane moves along. Fig. 23 illustrates a revolving pneumatic crane and serves to indicate the possibility of special devices to meet individual cases. This is a form of yard crane for loading or unloading cars or trucks. It can also be used in a machine shop, foundry, or elsewhere for placing pieces in machines.

We next come to the use of compressed air for operating special tools, such as drills, boring machines, flue-beaders and millers. At the present time there are a number of excellent forms of pneumatic drills on the market. These are made in different sizes for large or small work. One of their chief claims is the fact that they are easily portable and may be used in out-of-the-way places where other forms of drills could not be applied; or they permit drilling to be done on large pieces where they stand, without moving such pieces about, thus saving time and heavy lifting apparatus. In other words, the tool is taken to the work instead of the work being brought to the tool. Figs. 19, 24, and 26 afford good illustrations

WORKING RESULTS WITH PNEUMATIC DRILLING MACHINES.

No. 1 Machine

Drilling	½	inch	hole	through	1¼	inch	mild	steel	plate,	3	minutes,	15	seconds.
"	¾	"	"	"	1¼	"	"	"	"	4	"		
"	1	"	"	"	1¼	"	"	"	"	6	"	25	"
"	1¼	"	"	"	1¼	"	"	"	"	8	"	10	"

No. 2 Machine

Drilling	½	inch	hole	through	1¼	inch	mild	steel	plate,	5	minutes,	20	seconds.
"	¾	"	"	"	1¼	"	"	"	"	7	"		
"	1	"	"	"	1¼	"	"	"	"	11	"	30	"
"	1¼	"	"	"	1¼	"	"	"	"	13	"		

of the flexibility of these pneumatic drills.

By the use of such drills holes may be put in, ranging from ¼ inch to 3 inches, at a rate many times that possible by hand. The smaller sizes are very handy for putting on cylinder casings, name plates, and for general finishing work in and about large machines. They are extremely light and compact, use very little air, and are remarkably durable. The larger sizes, too, find a wide range of uses in any machine shop. The table above shows what some of these drills will do.

All these pneumatic tools may be provided with chucks or taper sockets, so that a variety of tools can be used. Once installed, they constantly suggest new uses, and prove their value from the start. In the boiler, machine, and other shops pneumatic tools of various sorts are installed for cutting stay bolts, reaming and drilling out boiler tubes, expanding new tubes, riveting, etc. A variety of other uses, more or less novel, have been introduced from time to time, all effecting marked savings in the respective operations to which they are applied.

Riveting may be regarded as apart from machine shop work, but here and there special work is turned out on which these tools can be used to excellent advantage. Examples of this are afforded by Figs. 29 and 30, which show a long-stroke hammer and pneumatic hold-up and a yoke riveter at work.

The table on page 17 is of interest and value as giving a definite statement of the saving in cost and time which may be effected by the use of pneumatic tools of different kinds. It is, as far as the writer is able to determine, accurate, and may be used in estimating on results to be obtained.

From a study of your product, conditions and process of manufacture in the light of the data given, it will be possible to determine upon what apparatus will be applicable to your case. Having selected the types, sizes, and number of pneumatic tools or apparatus you want, the total quantity of air necessary for immediate use can be determined. Allowance should be made for an increased demand, which invariably results after a plant of this kind is installed. The sum of these quantities determines the capacity of the compressor or compressors necessary.

Having determined on the number and location of the tools and the volume of air necessary, a piping or transmission system should be laid out, based on this information. Starting from the

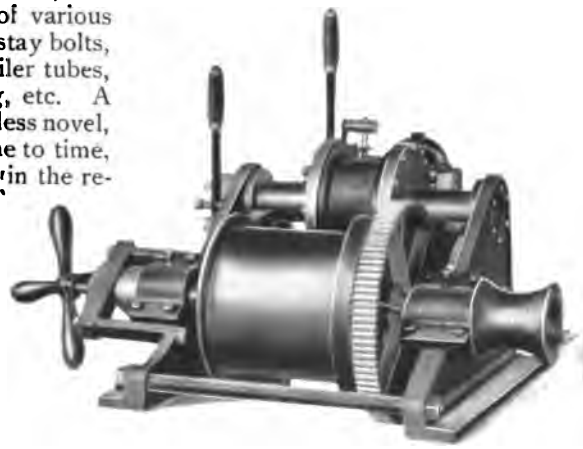


FIG. 14.—A PNEUMATIC HOISTING ENGINE MADE BY THE EMPIRE ENGINE & MOTOR CO.

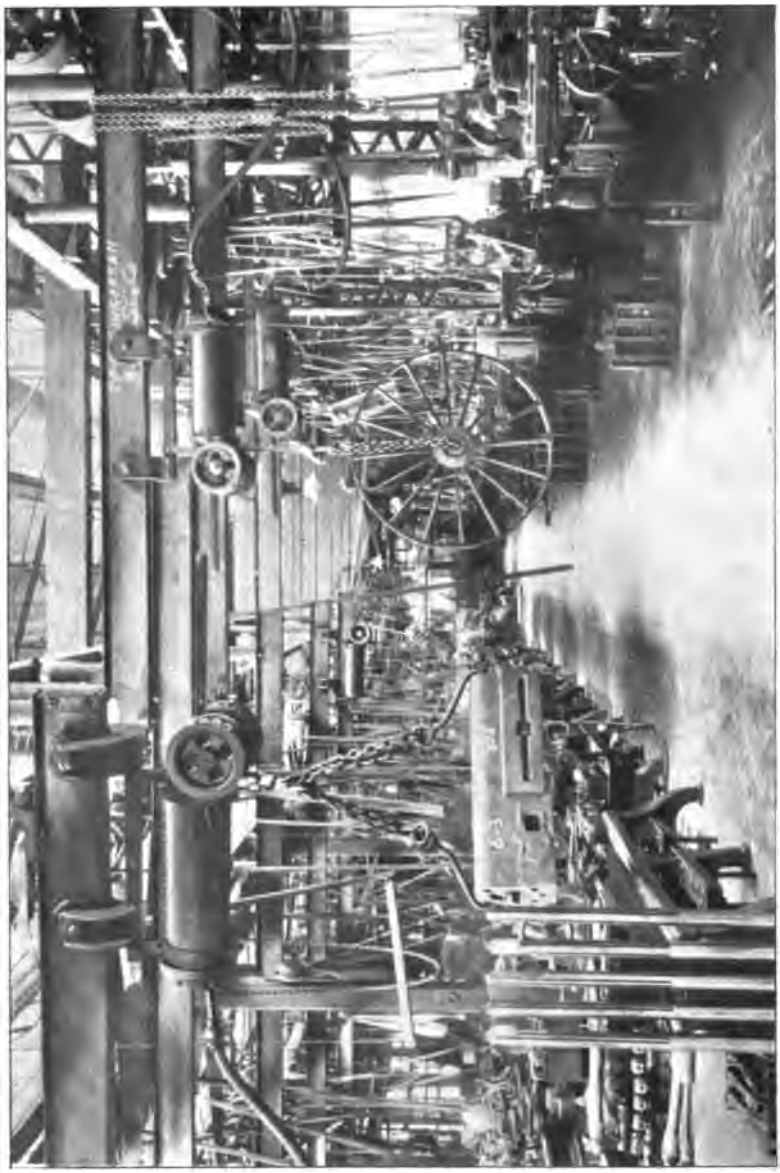


FIG. 15.—OVERHEAD HORIZONTAL PNEUMATIC HOISTS FOR HANDLING MACHINE WORK IN THE SHOPS OF THE INGERSOLL SERGEANT DRILL CO., EASTON, PA., U. S. A.

RESULTS OBTAINED WITH PNEUMATIC TOOLS.

Tool	General Character of Work.	Saving— Per Cent. of Cost.	Saving— Per Cent. of Time.
Pneumatic hammer	General foundry work—chipping	67–75	67–75
" "	Riveting on mud ring and fire-box	67	--
" "	Chipping flue sheet	84	75
" "	Beading flues	75	75
" "	General boiler shop work	60	--
" "	Cutting out broken fire-box stays	70	70
" "	Cutting off stay-bolt heads	58	--
Riveter	Boiler riveting	66	50
Drill	Drilling saddles	70	70
"	In general machine shop work	75	75
"	Drilling for stays	50	50
"	In general boiler-shop work	75	75
"	Facing steam pipes	75	75
"	Tapping for stays	65	--
"	Reaming crown sheet	70	--
Breast drill	General work	90	90
Staybolt nippers	Cutting off stays	73–90	75–90
Driving-box press	Pressing brasses	68	--
Paint sprayer	Painting box cars	67	67
" "	Painting car trucks	87	87
Paint burner	Cleaning off passenger cars	67	67
Sand blast	Cleaning tanks	90	83
Air jet	Cleaning cushions	50	50

location of the compressor, the piping should be run as direct as possible to the shop or shops where the air is wanted. Turns, elbows, and joints should be avoided as much as possible, as each of these imposes a certain amount of resistance to the free flow of air, and hence entails a loss of pressure. Where these cannot be avoided, long bends, Y branches, and 45-degree elbows should be used.

The table on page 19 shows the importance of this point and gives, in feet of straight pipe, the additional length which will cause a reduction of pressure equal to that caused by globe valves, elbows, and tees.

Generally, the air mains are run overhead, along the roof trusses close to main columns, down which branch pipes are run at frequent intervals to within a height of about 4 feet above the floor. These branches are usually closed by globe valves, fitted with a nipple to which the flexible hose may be attached. This arrangement admits of the greatest flexibility and permits the entire shop floor to be served with short lengths of hose.

Valves should be avoided as far as possible, as they also offer resistance to the free flow of the air. Where necessary, a type should be selected which has a wide opening without offsets or crooked passages, except in the smaller sizes, where, though desirable, these refinements are not essential.

In erecting piping, full lengths should be used, care should be taken to avoid couplings and joints, and the work should be done as thoroughly as with steam mains. Joints should be leaded, or, if flanged joints are used, gaskets should be carefully cut and fitted. This

FIG. 16.—A SMALL PNEUMATIC MOTOR FOR GENERAL POWER PURPOSES

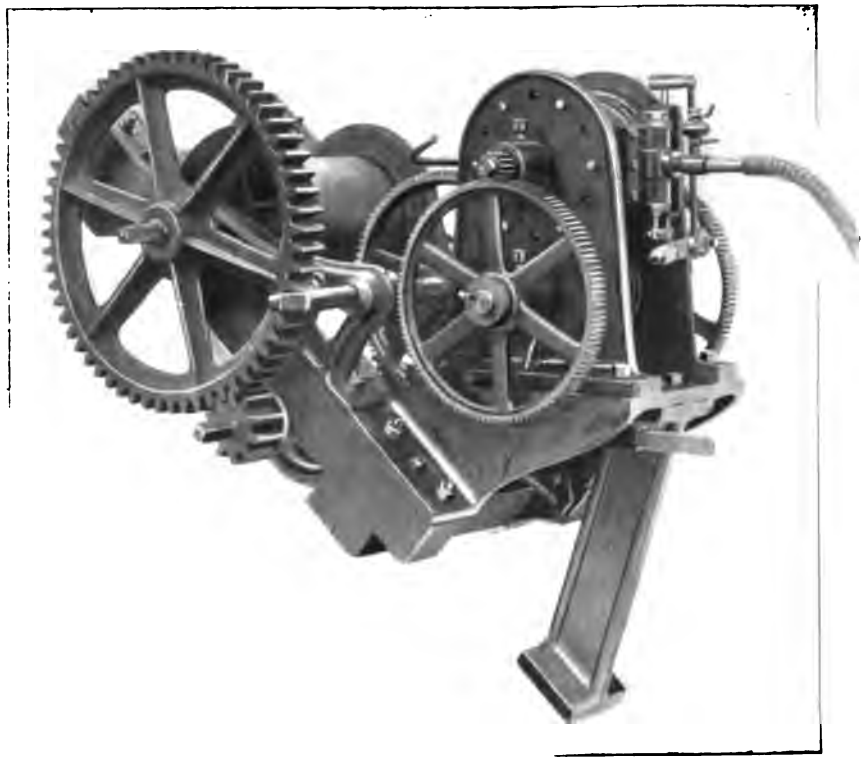


FIG. 17.—A PNEUMATIC CRANE MOTOR AND WINDING DRUM FOR BOOM OR OTHER CRANES

seemingly excessive care will pay for itself many times over in the saving of air. It should be borne in mind that every 5 cubic feet of free air require one H. P. for compression to 100 pounds per square inch. The pipes should be firmly supported, to avoid vibration or working; but expansion joints are not necessary, as the temperature of the air in the mains remains practically constant at about that of the shop interior, unless it is conveyed some distance in exposed pipes.

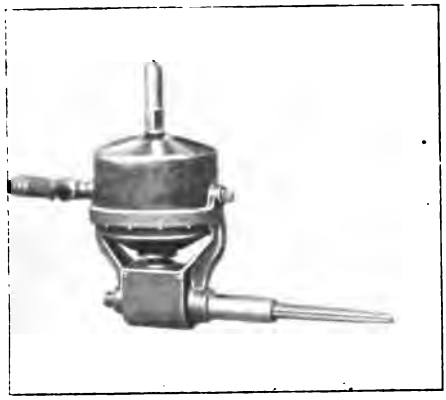


FIG. 18.—A PNEUMATIC DRILL WITH ANGLE ATTACHMENT FOR WORKING IN CORNERS

In some cases where the works are scattered over a considerable area it is necessary to put underground the mains leading to the remote shops. For this purpose they may be laid in the ground the same as water mains or drain pipes, or they may be supported in tunnels, boxes, brick ducts, or the like. This, however, is not essential. More often the pipes are placed on the ground surface or supported along the sides of buildings. Where the lines are long and exposed to the outside air, it is well to put in drip tanks or give the pipes enough slope to drain towards low points, where traps or drip loops should

be put to take care of any moisture which may collect. These traps should be drained from time to time, either automatically or by hand. The reason for this is obvious when it is remembered that compressed air, as usually produced, contains moisture which will precipitate when the air comes in contact with cooler sections of the pipe line. In any event, especially if the system is permanent, as is the case with a factory, all mains, both inside and out, should be securely supported and protected from material falling on them, rust, and other abuses.

A valuable feature of such a system of piping, to which attention should be called, is its utility in case of fire. For this purpose connection may be made to a suitable water supply, either city, private reservoir, or fire pump. On a prearranged signal, the air can be shut off and the water turned on, affording at once an abundant supply within a few feet of any part of the works in addition to any regular hydrant and sprinkler system.

When air is transmitted some distance to scattered shops, it is a good plan to place a receiver tank where it enters the building and to connect the shop piping system to this, the object being to reduce the velocity for a minute or so and permit any moisture to be

FRICTION OF AIR IN PASSING THROUGH GLOBE VALVES, ELBOWS, AND TEES

GLOBE VALVES.

Diameter of pipe, inches	1	1½	2	2½	3	3½	4	5	6	7	8	10
Additional length, feet	2	4	7	10	13	16	20	28	36	44	53	70

ELBOWS AND TEES.

Diameter of pipe, inches	1	1½	2	2½	3	3½	4	5	6	7	8	10
Additional length, feet	2	3	5	7	9	11	13	19	24	30	35	47

FIG. 19. – A PNEUMATIC DRILL FOR BRIDGE WORK. MADE BY THE NEW TAITE HOWARD PNEUMATIC TOOL CO., LTD., LONDON

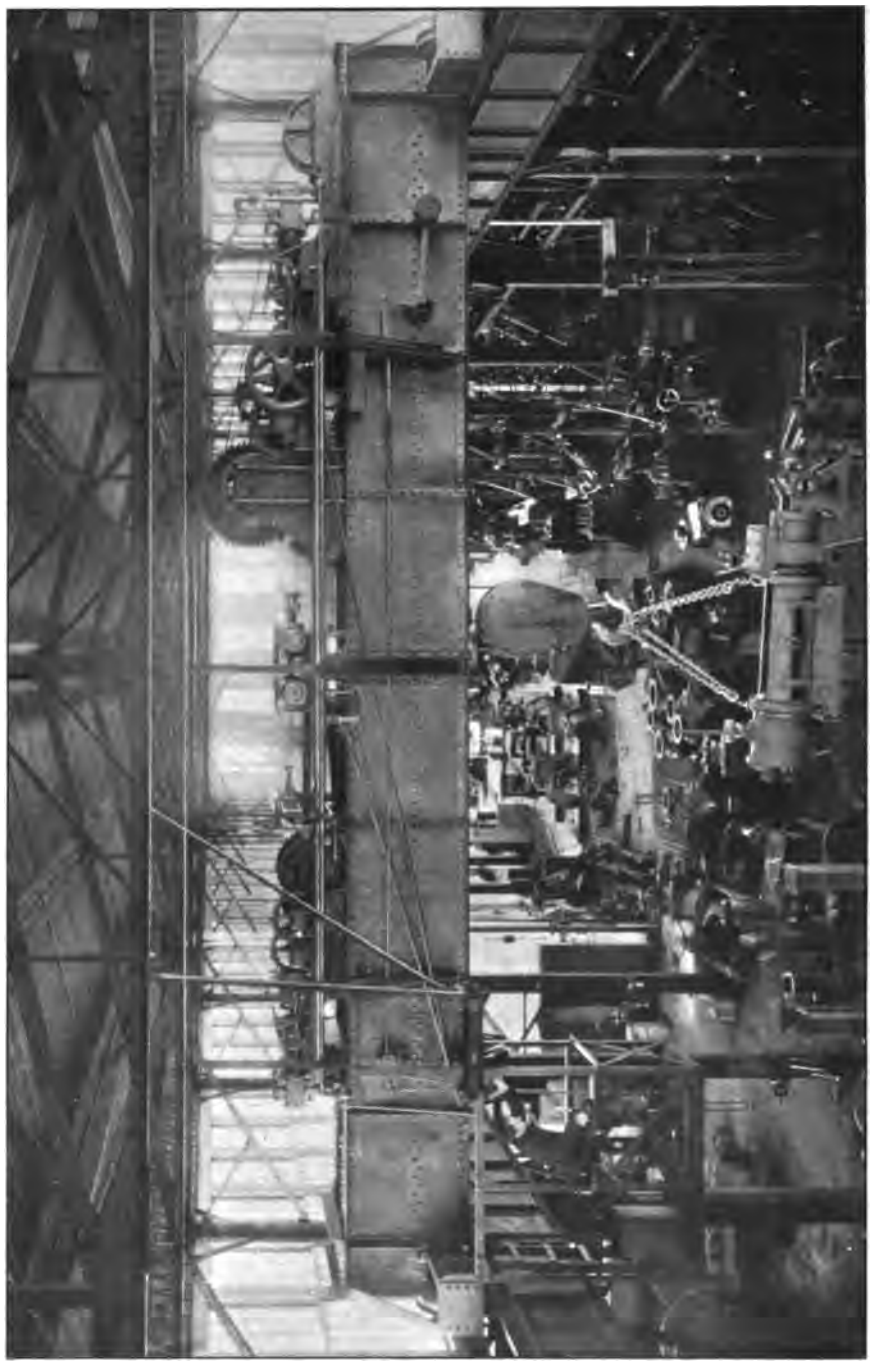


FIG. 20.—A 20-TON TRAVELLING CRANE, 35 FEET SPAN, IN THE SHOPS OF THE RAND DRILL CO., NEW YORK. THE THREE OPERATIONS OF LENGTHWISE AND CROSS TRAVEL AND HOISTING ARE PERFORMED BY THREE INDEPENDENT COMPRESSED AIR MOTORS. THE AIR SUPPLY IS CARRIED TO THE CRANE THROUGH A HOSE SERVING A 400-FOOT TRAVEL

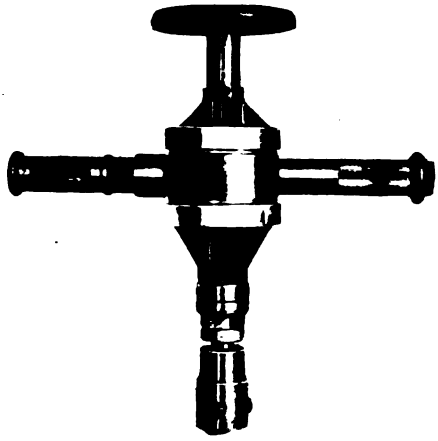


FIG. 21.—A TYPICAL SMALL PNEUMATIC DRILL

precipitated, as already explained. The receiver also acts as a balance spring and assists in maintaining a constant air pressure in the mains and at the tools. But it is not necessary, nor advisable, to have this large enough to act as a reservoir.

Sometimes when the air has been transmitted long distances, it is reheated after entering the building, and its temperature is considerably increased, with a resulting increase in volume. This reduces the velocity of the air flowing in the transmission main. It is stated that for short distances, not exceeding 500 feet in the case of a given pipe-line, the same results may be expected with air as with water; but for longer distances the efficiency of air transmission increases considerably. In any case, reheating is advisable where motors, hoists or other devices are employed which use a considerable volume of air expansively. Average experience shows that by this means the available air may be increased from 20 to 40 per cent.

The question of best size of mains is one calling for the balancing of a number of factors. When the actual amount of air to be used has been settled upon, the drop in pressure becomes the next point of importance. The smaller the mains, the greater the drop, the same as with the transmission of electricity; but, unlike electricity, an increase in the size of the line works a double advantage, for it at once reduces the loss in pressure, and the larger the pipe, the greater the reservoir capacity.

A " rule-of-thumb " to use in laying out piping systems for small plants is to avoid all pipes less than ¾ inch and not exceed in diameter the size of pipe given by the maker of the compressor as the diameter of the discharge pipe. In case two compressors are used, naturally the pipe from the receiver to where the air is used would have a section double the discharge area of the two compressors. The largest pipe should be nearest the compressor or receiver, and the size should be reduced after each branch. The ¾-inch size refers to the cylinder branches to which the flexible hose is attached.

It is well to insist on an inspection of the piping system at regular intervals to avoid leaks which are wasteful and altogether unnecessary. On account of

FIG. 22.—A PNEUMATIC CHAIN HOIST MADE BY THE INTERNATIONAL PNEUMATIC TOOL CO., LTD., LONDON.

FIG. 23.—A PORTABLE REVOLVING PNEUMATIC CRANE MADE BY THE GARRY IRON & STEEL CO., CLEVELAND, OHIO, U. S. A.

escaping air being harmless and invisible, it is often the case that leaks are tolerated which, if water or steam were used, would bring severe criticism on the engineering staff. When it is remembered that a pipe or reservoir containing air at 100 pounds gauge pressure will leak about 6½ cubic feet of free air per minute, or 3870 cubic feet in ten hours, through a 1-16 inch hole, which means something over one horse-power, the importance of a tight piping system is apparent. Ten or a dozen such leaks will constitute quite an item, and one which can be avoided entirely by proper inspection when erecting, and a little care from time to time afterwards. We have now traced the subject backward from the use of compressed air through the means of transportation to its origin, and it now remains to treat only of its production. There are a few places where compressed air can be produced by means of the hydraulic or falling water system, which may be called the reverse of the Pohlé air lift pump. There are other places where compressed air can be produced by water power-driven compressors, and there are many opportunities where compressors of this sort could be installed and the power transmitted long distances. Many such compressors are in operation in moun-

tainous districts for mining plants. But by far the larger number of factories are so situated that air must be obtained by means of steam compressors, or belt or electrically-driven machines, and the writer will, therefore, confine himself to these types.

On the proper selection of the air compressor is dependent very largely the entire success of a compressed air installation. The compressor is the source and regulator of the power, and as all the other working apparatus and the final results rest on the character of the compressor, this certainly should not be the weakest link in the chain. Often, after a due regard of the features already mentioned, works managers neglect the pivot on which turns the entire plant and install a cheap or inefficient machine. An air compressor is a machine very different from a pump or even a steam engine, both in design and construction. Many things are permissible in steam engine construction which should not be tolerated in an air compressor, especially if intended for high pressures. It is doubtful if most people and many engineers realise this point, but it is a fact that cylinders, coolers, pipes, and other parts apparently good and which, if used for steam pumps or engines, would pass a careful inspection, must often be rejected for compressed air service because they are porous and allow air to leak through.

It must be remembered that the compressor becomes part of the central power plant, the shutting down of which

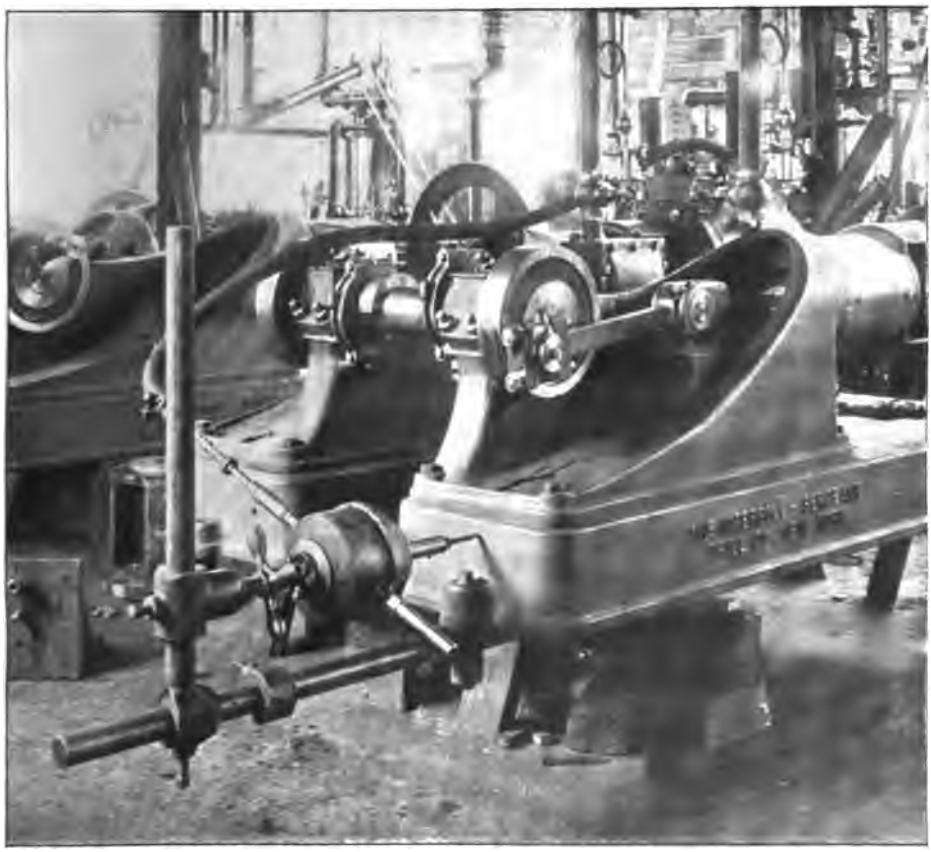


FIG. 24.—A METHOD OF MOUNTING A PNEUMATIC DRILL, ILLUSTRATING ITS PORTABLE CHARACTER

FIG. 25.—DRILLING OUT STAY HOLES IN A LOCOMOTIVE FIRE BOX AT THE PARIS EXHIBITION OF 1900 WITH A PNEUMATIC DRILL MADE BY THE NEW TAITE HOWARD PNEUMATIC TOOL CO., LTD., LONDON

for twenty-four hours, resulting from a serious accident, may cause as much loss to the user as would half pay for the machine. Constant repairs, even though each single one may be small in itself, when added together may more than equal the extra amount in the cost of a better compressor at the start. It is possible and often wise to experiment with the small things about works in an effort to reduce costs; you can afford to buy several hundred files of some new make, or two or three pneumatic tools of this make or that, and give them a test, because these are incident to the business. But the compressor, like your boiler, forms part of the heart of your establishment, which must throb whenever called upon, and you cannot afford to experiment with it. The safest rule in this respect is to ge the best, but do not expect to ge

APPROXIMATE DATA ON WEIGHTS, CAPACITY, COSTS AND OPERATING EXPENSES OF STANDARD AIR COMPRESSORS ON A BASIS OF 100 LBS. AIR PRESSURE (GAUGE AT RECEIVER) AND 100 LBS. STEAM PRESSURE (AT THROTTLE).

Type of Compressor.	Form of Valve Used.	Steam Consumption lbs. per H.P. per Hour. Non-condensing.	Steam Consumption lbs. per H.P. per Hour. Condensing.	Weight of Compressor per cu. ft. of free Air Piston Displacement.*	Compressor Capacity in Cubic Feet of Free Air (Piston Displacement.)	Cost of Compressor per Cubic Ft. of Free Air Piston Displacement.*	Cost of Compressor per Indicated H.P. Steam 100 lbs.	Cubic Feet of Free Air (Piston Displacement) per 1 H.P.†	Total Cost of One Cubic Foot of Free Air Piston Displacement. Considering a 10-Hour Day, Coal at $5 per Ton, Usual Labour, Depreciation and Interest Expenses. ††
Straight Line	Simple-slide and Meyer's	35	28	53 to 29	24 to 1375	$17.00 to $4.50	$80.00 to $22.00	4.0 to 5.	.002 cts. to .004 cts.
Duplex type self-contained	Meyer's adjustable	35	28	76 to 28	50 to 470	18.00 to 5.10	90.00 to 26.60	4.8 to 5.	.007 cts. to .004 cts.
Duplex extension frame	Meyer's adjustable	35	28	34 to 24	345 to 2200	7.00 to 3.00	32.00 to 24.00	4.6 to 4.7	.003 cts. to .004 cts.
Compound extension frame	Meyer's adjustable	29	20	43 to 32	320 to 1900	9.00 to 4.00	47.00 to 25.00	5.5 to 6.	.0038 cts. to .002 cts.
Corliss compound steam duplex air	Corliss	..	20	75 to 53	550 to 5700	7.00 to 4.30	41.00 to 21.00	5. to 4.8	.0039 cts. to .0017 cts.
Compound steam compound air	Corliss	..	18	71 to 47	600 to 3700	7.80 to 4.70	42.00 to 23.00	5.3 to 5.7	.003 cts. to .001 ct.

* Not including condenser. † Working full load. †† Considering full output.

it as cheaply as the inferior article. Another point to bear in mind when selecting a compressor is to allow the manufacturer to advise you, presuming that you are dealing with a reputable concern. Many people fail to realise that it is to the compressor builder's interest to satisfy the purchaser. All the types of compressors he makes will compress air, but each type is designed for a certain class of work, and he knows better than you which machine will best fulfill your wants. Anything that compresses air is not an air compressor from your standpoint. Air brake pumps compress air, but they use from four to five times as much steam as a regular air compressor of the same capacity requires. Some one in your neighbourhood may have a small compressor of given make running a sand blast, but it does not follow that the same concern will build for you a larger compressor to work as well.

The rapid increase in the use of compressed air has brought into the field new concerns, but you need not feel that they were born, Venus-like, "full-grown." They are learning by experience something which cannot be injected, like opium, with a hypodermic syringe. Nor does it follow that the oldest is the best, for sometimes the "old-fogy" element creeps into compressors, as well as into other things.

Many manufacturers in buying supplies will look ahead weeks and months and lay in an ample supply of raw materials. It may be a thousand tons of coal in excess of what is wanted, because prices are low, or it may be a six months' supply of pig-iron or the like; but when they come to buy an engine or an air compressor they almost invariably buy only what is needed for present wants. New uses for the compressed air arise constantly, and devices formerly driven by steam, water or electricity, or worked by hand, are found to operate better with air, so that in a surprisingly short time the capacity limit of the machine is reached, and often exceeded, with the result that, without much thought, the compressor is criticised for poor performance when really

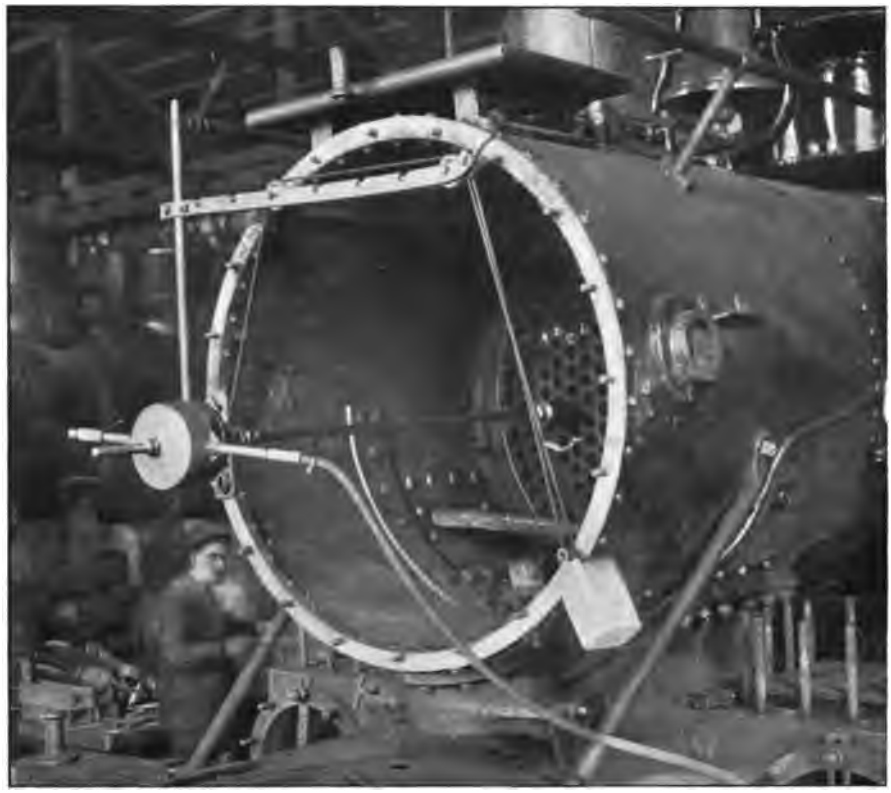


FIG. 26.—EXPANDING BOILER TUBES WITH A PNEUMATIC TOOL

it is overworked, and hence abused, and a new and larger machine must be bought, the total cost of all this being greater than the cost of the larger machine would have been in the beginning. It is always better to work a little under the rated load and speed.

In discussing air compressors, remember that the manufacturers' invariable rule is to rate their capacities according to the theoretical output of the cylinder, making no deduction for piston rod clearance, friction, heating, or slip. It should be distinctly understood whether theoretical or practical capacity is given. The table on page 25 will be of assistance in figuring on costs of installation and operation; but the cost figures should not be taken too literally, as they are intended to give maximum values which are safe.

The style of compressor to be selected depends upon what may be termed local conditions, that is, whether water-power is available, or whether electricity can be obtained at a reasonable rate, or is produced in a central power station and transmitted to several shops; or whether it is desired to use a belt compressor or a steam-driven type. Compressors designed for each of these conditions are available in the market, and in various modifications of each class.

In conclusion, it may be of interest to know the experience of a few large concerns who have adopted compressed air apparatus. One of these is the Passaic Rolling Mills, of Passaic, N. J., a concern employing about 1200 men, with a monthly output of about 5000 tons of structural material. A complete system was installed, with an air compressor conveniently placed and air mains run to various departments scattered over an area of about twenty-five acres. Air is used for almost every

variety of work that can be found about an establishment of this character. In connection with the transfer tables and rolls the use of air permitted four men doing the work formerly requiring thirteen, and trebled the capacity of the roll. The cold saws operated in conjunction with the rolls were arranged to be elevated by air. Forty cylinder hoists, twelve riveters, and two chipping tools were also installed, and have been giving excellent satisfaction.

A second case, of a different type of plant, which could hardly be called a machine shop, yet serving as an example of the utility of compressed air, is that of the Tide Water Oil Company, of Bayonne, N. J., where fourteen pumps and other machines, all previously driven by steam, were arranged to be driven by compressed air, with a saving which, to say the least, was remarkable, as the necessary boiler capacity was reduced 178 H. P. by the introduction of the central plant. In this way a yearly saving of $4450 was effected. Another example is the repair plant of the Manhattan Elevated Railway, in the city of New York. In this plant a

FIG. 27.—A PORTABLE PNEUMATIC PUNCH MADE BY MESSRS. F. F. SLOCOMB & CO., WILMINGTON, DEL., U. S. A.

FIG. 28.—PNEUMATIC TOOLS USED IN EXPANDING BOILER TUBE ENDS IN THE SHOPS OF MESSRS. YARROW & CO., LTD. LONDON

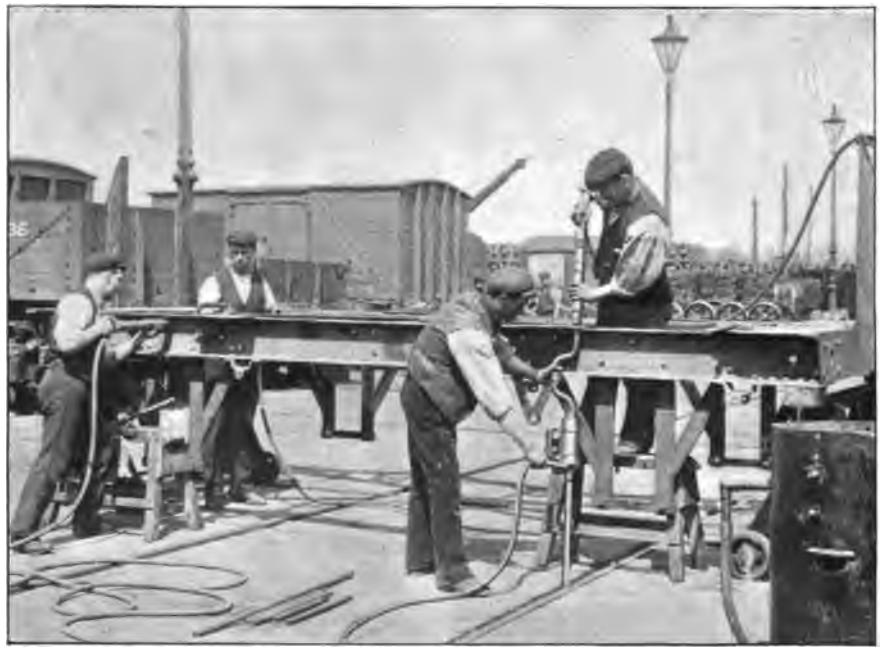


FIG. 29.—A PNEUMATIC RIVETING HAMMER AND HOLD-UP AT THE TEMPLE MILLS WORKS OF THE GREAT EASTERN RAILWAY. MADE BY THE NEW TAITE HOWARD PNEUMATIC TOOL CO., LTD., LONDON

FIG 30.—A SMALL-SPAN YOKE RIVETER FOR STRUCTURAL AND SPECIAL TANK WORK

number of air hoists and pneumatic cranes were installed, enabling one man in one minute to do work which formerly required two men four minutes.

Still another example, and perhaps one more generally interesting, is furnished by the Baldwin Locomotive Works, of Philadelphia. The present equipment of compressed air shop appliances at these works consists of the following:—

A generating plant of ten compressors of various types aggregating 450 horse-power, according to the builder's rating. These compressors range in size from 6 horse-power to 80 horse-power capacity. They are run night and day up to their full capacity, and the actual power developed is generally considerably above the builder's rating. Local conditions render it impossible to utilise a central power station. It was, therefore, necessary to locate the generating plants at three distant points, the supply of air from two of these stations being connected, and the third being entirely independent of the other two. Nine air reservoirs are installed in connection with the compressors, having an aggregate capacity of 1650 cubic feet with a maximum pressure of 90 pounds per square inch.

There are in operation 115 drills, of which 83 are in use in the boiler shop, 20 in the erecting shop, and 11 in the tank and tender shop for reaming and tapping for stay-bolts. The advantage of being able to bring the tool to the work in place of taking the heavy work to the tools effects a considerable saving. Previous to the adoption of compressed air machinery in this plant this class of work was done entirely by hand. Considerable annoyance was at first experienced by the oil, necessarily used in large quantities, coming in contact with and softening the rubber hose used for supplying the air to the drills. After some experimenting, a hose covered with duck and treated with boiled linseed oil was adopted, resulting in quite a reduction in the cost of maintenance.

Three bolt-cutting devices are used for cutting off the projecting ends of boiler stay-bolts after they have been screwed into place. These have proved

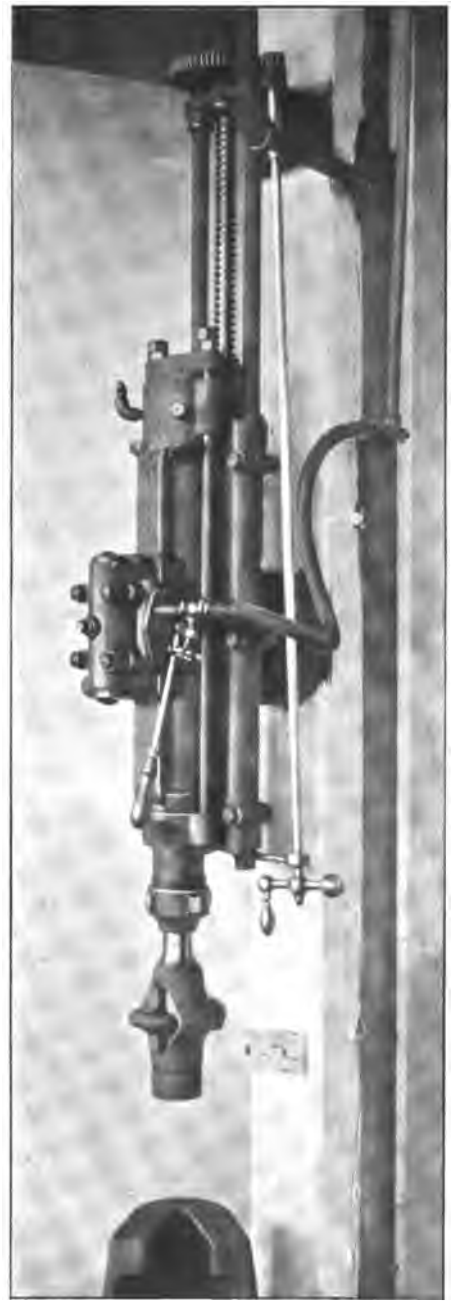


FIG. 31.—A ROCK DRILL ARRANGED AS A BLACKSMITH'S HAMMER BY THE RAND DRILL COMPANY, NEW YORK

FIG. 32.—A PNEUMATIC RIVETER AND A "HOLDER-ON." MADE BY THE CLEVELAND PNEUMATIC TOOL CO., CLEVELAND, OHIO, U. S. A.

themselves not only labour-saving, but the results obtained are much more satsfactory than with the old method of chipping the ends off by hand, as the use of the hammer and the chisel was liable to loosen the bolts in the thread. This is entirely avoided by the improved process. The apparatus, when swung rom a jib crane, can be easily managed and operated by one man, and will cut off the stay-bolts much more rapidly and neatly than by the old method.

Seven hammers for calking the seams if tender tanks are used in the tender shop in addition to a number of heavier hammers in the boiler shop for chipping purposes.

Pneumatic moulding machines in the foundry are used to mould small patterns which are symmetrical, and where a large number of pieces from the same pattern are required, such as brake heads, brake shoes, etc. The process is completed with great rapidity, and the capacity of the machine is limited only by the speed with which the operator removes the finished flakes and supplies fresh ones to be operated upon.

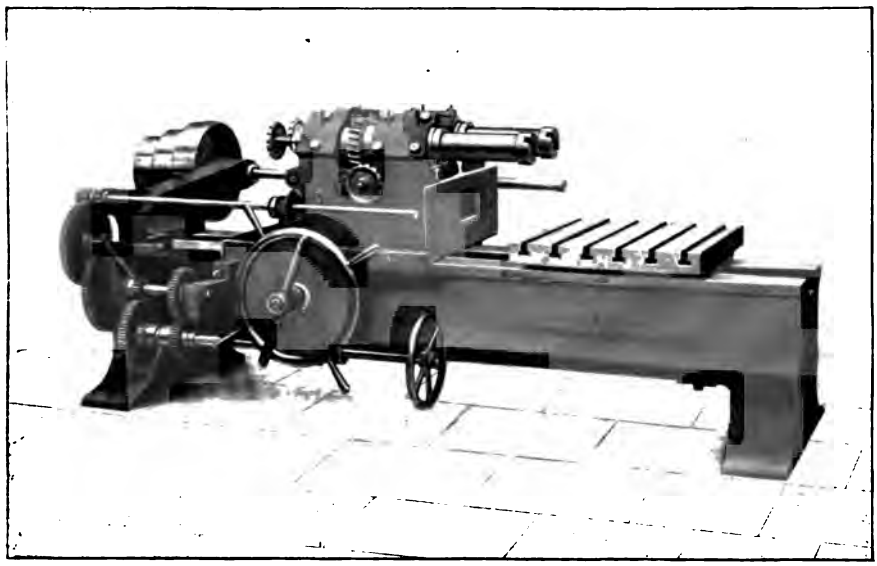
THE MULTIPLICATION OF CUTTING TOOLS

A GROWING TENDENCY IN MACHINE TOOL DEVELOPMENT

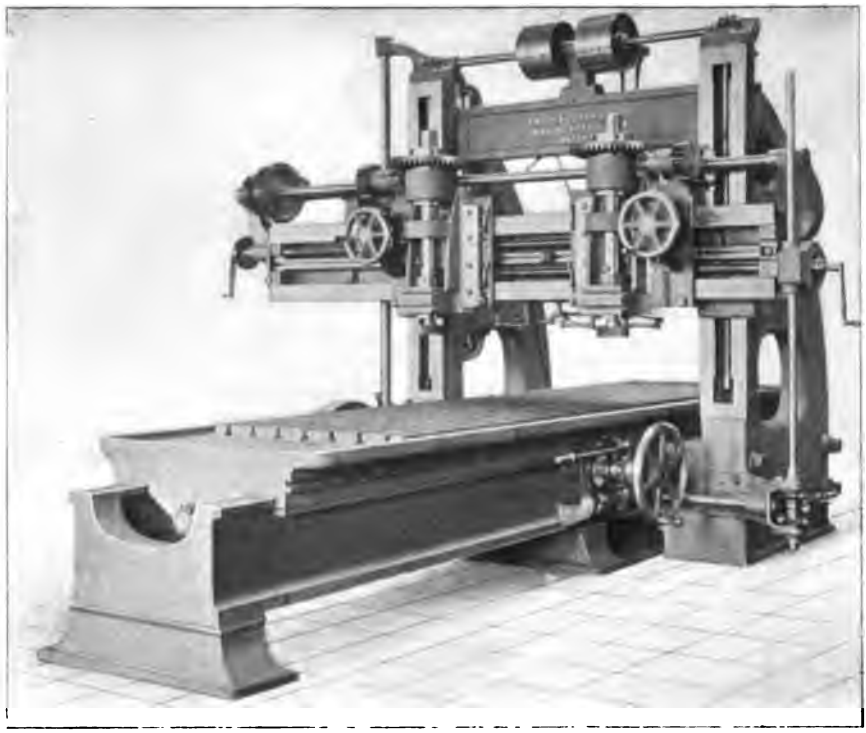
By Joseph Horner

IT has been said that the man who makes two blades of grass grow where but one grew before is a benefactor to his race. Equal honour might be accorded to the machinist who operates two cutting tools in place of one, for in so doing he helps to lighten the labour of the world. From just this one point of view it is proposed here to consider machine tools.

The employment of a single cutting tool is obviously a very tenacious survival from the time when all tools were operated by hand. From the single hand tool, used for turning, drilling, or chipping, the transition is natural to the same kind of instrument placed in a machine and operated by power. Use and custom are tenacious and long-lived, and so, while great advances have been made in some classes of automatic machinery used for spinning, weaving, and the like, the single cutting tool, in harmony with hoary precedent, has been perpetuated in machine design for a hundred years, and remains embodied now in by far the largest number of mechanisms that are employed in shaping metal. One machine, one tool, one man has been the rule, exceptions to which have been regarded with little favour. The aim has been in the direction of improving the single cutting tool itself, in developing its maximum efficiency by attention to angles, and so on. We must first consider, therefore, the limitations of the single cutting edge. Though the correct formation of tool



A DUPLEX BORING MACHINE WITH ADJUSTABLE SPINDLES ON MOVABLE HEAD, USED FOR CYLINDER AND PUMP WORK. BUILT BY MESSRS WM. MUIR & CO., LTD., MANCHESTER, ENGLAND



A DOUBLE-SPINDLE MILLING MACHINE MADE BY MESSRS SMITH & COVENTRY, LTD., MANCHESTER, ENGLAND

edges is a matter of much importance, it is not in harmony with practice to lay down very hard and fast rules relating to it. The statement is often made that certain angles must be adhered to for cutting cast iron, wrought iron, cast steel, forged steel, and brass; that in circular work the tool point must be exactly level with the axis of the work, and so forth. That such precise rules do not exist outside of books is borne out by daily experience, for, in the first place, they fail entirely to take account of the great differences in texture that occur in metals and alloys of the same name, but which differences have to be reckoned on in the shops.

In the second place, they are opposed to the fact that these angles are never observed within several degrees even in the general work of the shop, and that when tool points are used a compromise has to be made for the purpose of securing uniformity in grinding; also, that tools are seldom adjusted precisely level with the centre, and that convenience of holding, operating, and grinding them and their permanence of edge are as important from the economical point of view as adherence to such rules,—correct though they may be in theory. In other ways also theory and practice do not coincide.

The various elements which conduce to the efficiency of cutting tools are the formation of their edges, speeding and feeding, lubrication, and their continuous or intermittent action. These must be considered separately.

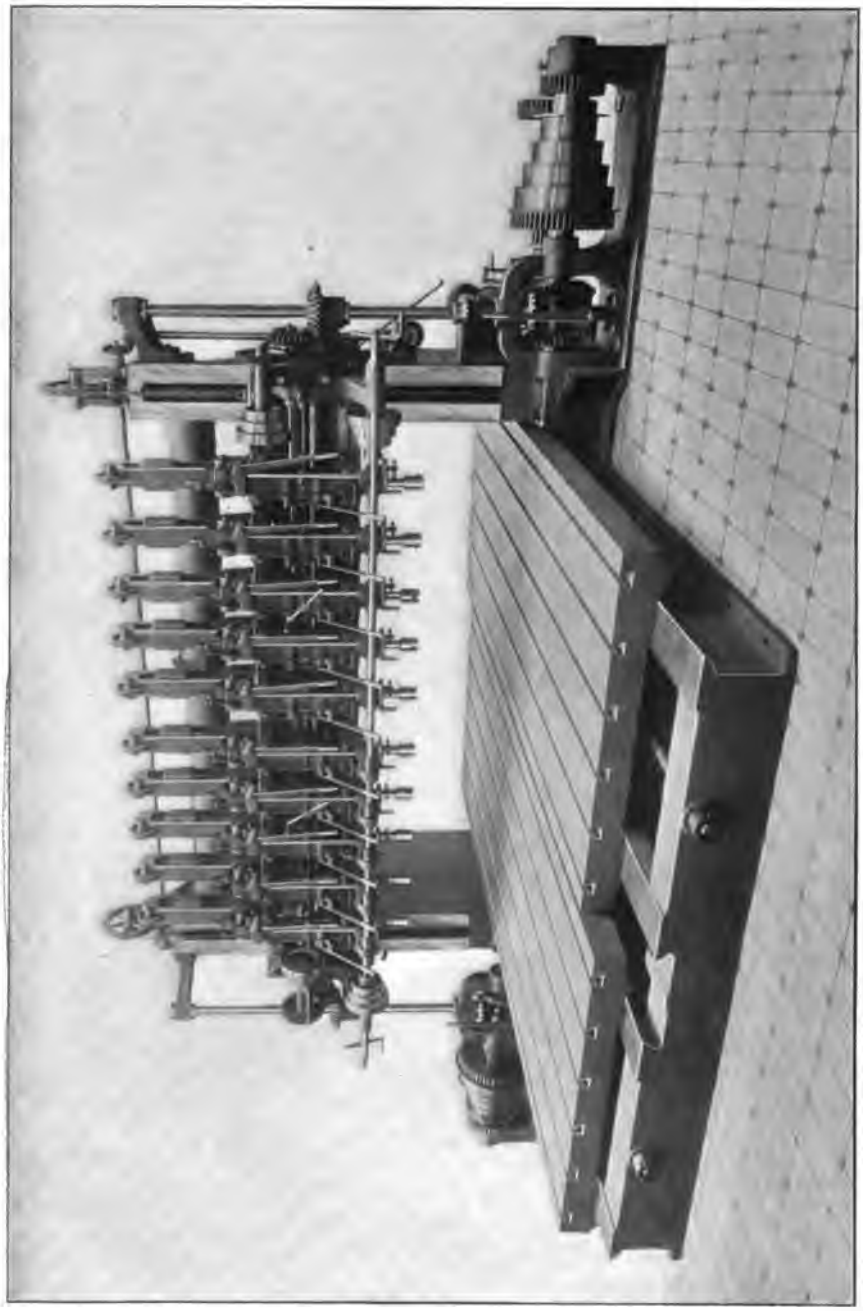
Tool formation involves three essentials,—penetrative capacity, clearance, and strength, each of which is, to some extent, opposed to the others, so that a cutting tool is a practical compromise, because there is no ultimate test for its efficiency save that of practice. The test is the amount of material removed in a given time consistently with the

permanence of the tool edge and with the accuracy of the surface cut. From this point of view the question of the keenest cutting edge can never be considered alone, since it must continue cutting for many hours, in some cases even for many days, without being removed for regrinding. The less regrinding is necessary, the less resetting has to be done.

As long as a tool remains fixed in its holder and capable of clean cutting, any number of pieces of work can be shaped to uniform size within the gauge limits allowed. This explains why the very exact rules for tool angles which have been sometimes laid down by writers on this subject find no such exact applications in the shops. As there is no uniformity of texture in materials of the same name operated on, nor in the conditions under which they are cut, limits as broad as, say, 10 degrees are practicable in fixing the various angles for tools for nominally similar materials, but of different qualities. These angles are arrived at tentatively in the first place. If a tool loses its edge too rapidly, the clearance angle is reduced. If it does not cut with sufficient keenness, the angle of top, or front, rake is increased. If it is not durable enough, the tool angle, or that which is measured between the top face and the clearance, is increased. These three, —always included between an angle of something less than 90 degrees, —are, therefore, made subject to variation to suit the nature of the work being done, and they are settled by practical test until that point is reached at which they are found to be most efficient in the sense both of cutting capacity and permanence of form. Beyond this it is quite impossible for the formation of single-edged tools to go. The law is applicable alike to tools of the lathe and planer, those for drilling and boring, and to the tap and die. The stage at which no more efficiency is possible in the cutting action of the single tool may be considered as having been reached in shop practice at the present time.

To increase the speed of a tool in-

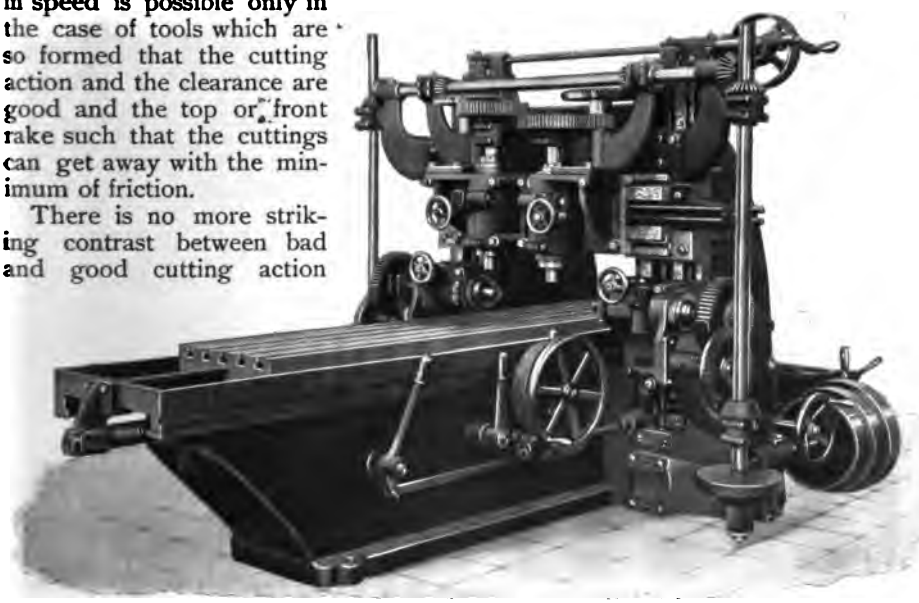
A MULTIPLE-SPINDLE DRILL MADE BY THE PRATT & WHITNEY CO., HARTFORD, CONN., U. S. A.



A TEN SPINDLE DRILLING MACHINE FOR WATER-TUBE BOILERS. THIS MACHINE DRILLS TEN 1¼-INCH HOLES, ONE INCH DEEP, IN ONE MINUTE. MADE BY MESSRS. JOHN HETHERINGTON & SONS, LTD., MANCHESTER, ENGLAND

creases its efficiency up to a certain point. To speed up a machine so that the cutting action becomes more rapid seems a very obvious method. But just here increased friction also comes into play, due to the larger number of chips which slide over the tool point in a given time, and for this reason higher speeding up is limited by the too rapid generation of heat, which is ruinous to the tool and detrimental to the accuracy of the work. Any important increase in speed is possible only in the case of tools which are so formed that the cutting action and the clearance are good and the top or front rake such that the cuttings can get away with the minimum of friction.

There is no more striking contrast between bad and good cutting action than that which is afforded by the old screwing dies which squeezed and scraped and got hot, and those now used in the modern screwing machines, in which the conditions named above are carried out absolutely. Another element is that of fine feeding combined with high speeding. In roughing-down stock in the turret lathe the feeds are fine, though the depth of cut is often great. By the adoption of fine feeds combined with higher speeds the rate of cutting of twist drills has been increased, the speeds in some cases ranging from 50 to 100 per cent. higher than they were five or six years ago. Speeding depends also on the nature of the chips removed. The short, crisp chips of brass and cast iron are no sooner severed than they fall away from the tool, permitting of more rapid cutting than the long, tough shavings of wrought iron and steel which move in close frictional contact with the top face of the tool. This consideration raises at once the question of the importance of lubrication, for if the heat can be removed from the tool point as rapidly as it is generated, the final and only possible element left which makes for efficiency is secured.



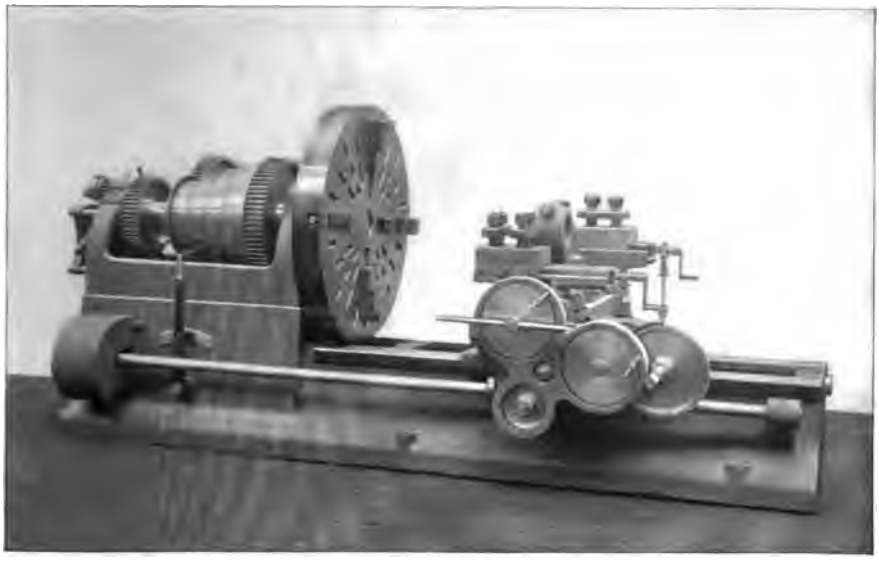
A PLANER TYPE MILLING MACHINE WITH TWO VERTICAL AND TWO HORIZONTAL SPINDLES, MADE BY THE BEAMAN & SMITH CO., PROVIDENCE, R. I., U. S A.

The improved methods of lubrication which have entered into recent practice mark a new and great advance. They have been, and are still being, developed rapidly on the automatic machines for screw and hub making and the like, on milling machines and turret lathes, etc. Formerly the only method of lubrication was that afforded by the drip can,—still retained on common lathes and machine tools,—a most inefficient device, though better than nothing. The later developments in-

A SHOP FULL OF AUTOMATIC SCREW MACHINES MADE BY THE CLEVELAND MACHINE SCREW CO., CLEVELAND, OHIO, U. S. A.

volve the distribution of oil through a spreader, or a plain tube, the oil being pumped under very considerable pressure. It is not easy to make exact comparisons between the old and the new arrangements, but it is certain that the capacity of tools has been fully doubled by the new methods of lubrication and probably to an even greater extent.

It seems, therefore, certain beyond question that the highest capabilities of the single tool have been reached in the best machines, though their efficiencies



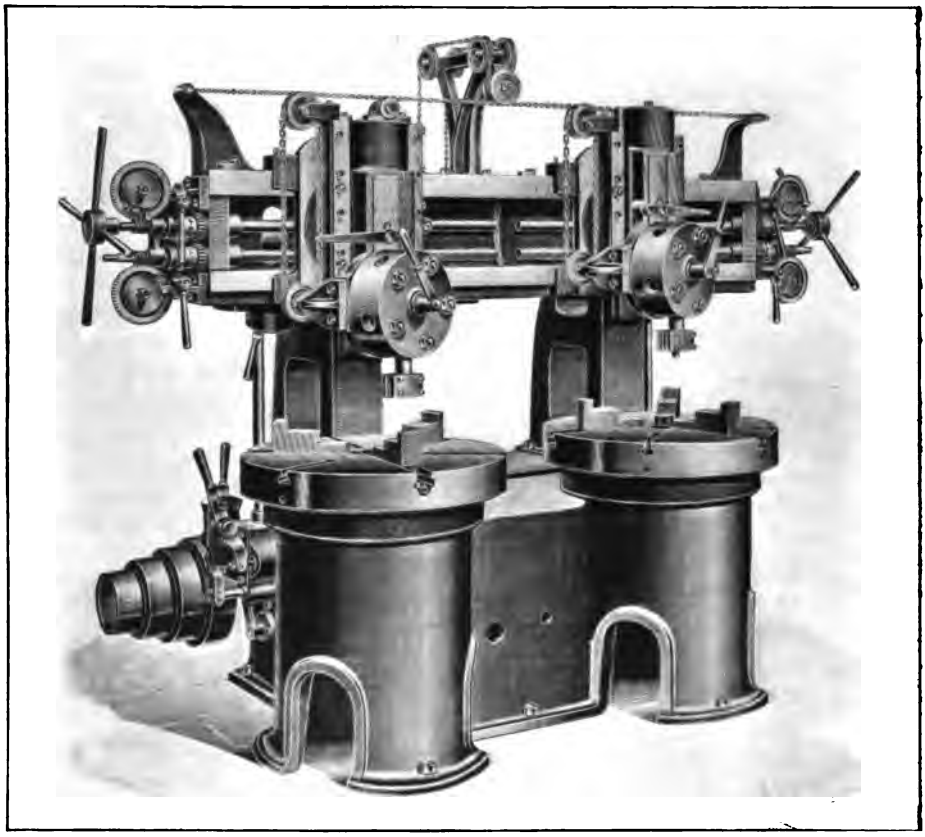
A SURFACING AND BORING LATHE WITH DOUBLE RESTS, MADE BY MESSRS. JOHN LANG & SONS, JOHNSTONE, NEAR GLASGOW

are not utilised as they might be in the average shops. From this higher vantage ground the machinist has but one course open, namely, to substitute several tools for the single edge. The continuous or intermittent action of tools lies outside the question of their cutting action and will be noted immediately.

The invention of the planing machine early last century, followed by that of the slotter and the shaper, effected a revolution paralleled only by that of the slide rest. In these reciprocating machines something has been done in the way of multiple cutting. Four tools are not uncommonly used on a large planer at one time. Two are fitted on the cross-rail, and one on each upright, —all with compound slides and having variable automatic feeds. The heads are in some models made one sided to permit the tools to operate as close together as practicable.

As the reciprocating movement of the planer and its allied types renders the tools inoperative during a portion of the time, and as the return stroke cannot be eliminated, the only course left is to quicken it. But the difficulty of reversing a heavy table without shock, due to its momentum, is well known, and here the limits have probably been reached. In belt-reversing machines rates of from 70 to 80 feet per minute are embodied in some of those of the best manufacture, but these speeds are above the average. The result is that in the best planers one-fourth the time is lost in return strokes, while one-third would be a fair average. In the Sellers spiral-geared machines operated by friction clutches the exceptional rate of 144 feet per minute is obtained in the return stroke.

The reversing tool box,—cutting in each direction,—was designed to avoid



A DOUBLE BORING MILL BUILT BY MESSRS. WEBSTER & BENNETT, COVENTRY, ENGLAND

this loss of time; but the slight extent to which it has been employed is due to the difficulties attendant on the performance of accurate work with such a device. Several have been made, but, though used, they are neither common nor popular. In plate-edge planing machines the tool boxes reverse and cutting is done in both directions, so that there is no loss return stroke, but the work is not of so fine a character as that of the machine shop. The most complete plate-planing machine includes two cutting tools operating on one edge and another cutting an end.

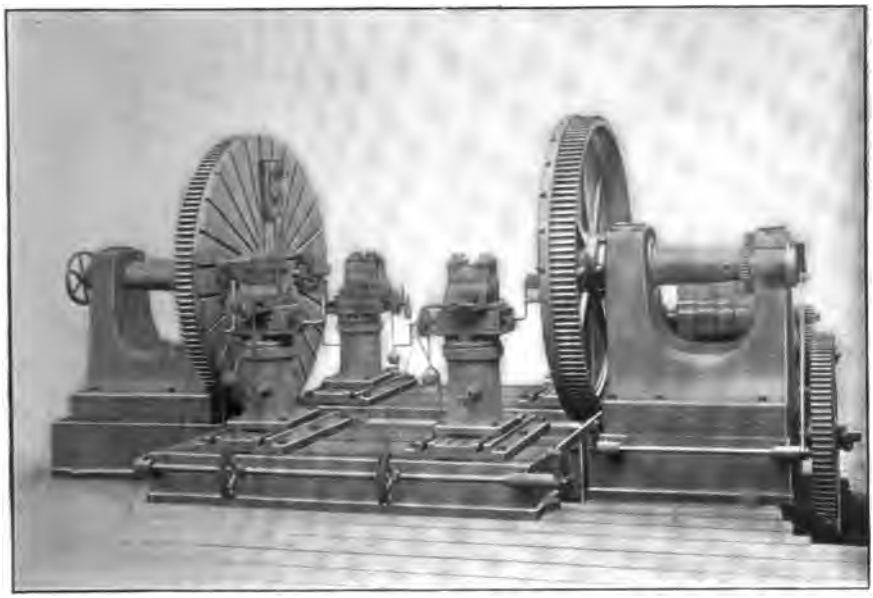
The double-headed shaper is economical because one man is able to attend to it. This design is not capable of wider adoption because the machines are only partiallv automatic, and because the operations are not often very prolonged. Shaping deals mostly with surfaces of small area for which frequent changing of the work and attention are necessary. Another advantage of a double-headed machine is that setting of work may be proceeding on one while the other is cutting, an arrangement for which some tools are designed, even though not duplicated in the sense of being simultaneous in action. Examples of this occur in milling, boring, drilling and other machines having double tables.

In the slotting machines fitted with a single ram the tool holder in most cases permits of the employment of a couple of tools set parallel with each other, a device by which two opposed faces may be slotted simultaneously, either on the inside of a piece of work, as an axle box, or on the outsides of brasses.

Heads are mutiplied in the locomotive frame plate slotters, in which case either two or three heads are fitted, each being driven independently, with quick return and balanced, while longitudinal and cross feeds are variable and independent.

Apparently none of these machines can be safely speeded higher than they are now in good practice for given depths of cut and feeds. Nor is there scope for the more efficient action of the tool, nor can their operations be further multiplied; neither is any advantage to be gained by the employment of reversing tool holders, nor in increase in the speed of the return stroke. It would appear, therefore, as if their limitations, as far as output is affected, are reached, or nearly so, in the best types, and so probably we shall advance little farther in any shop to be discarded wholly in favour of continuous cutting machines.

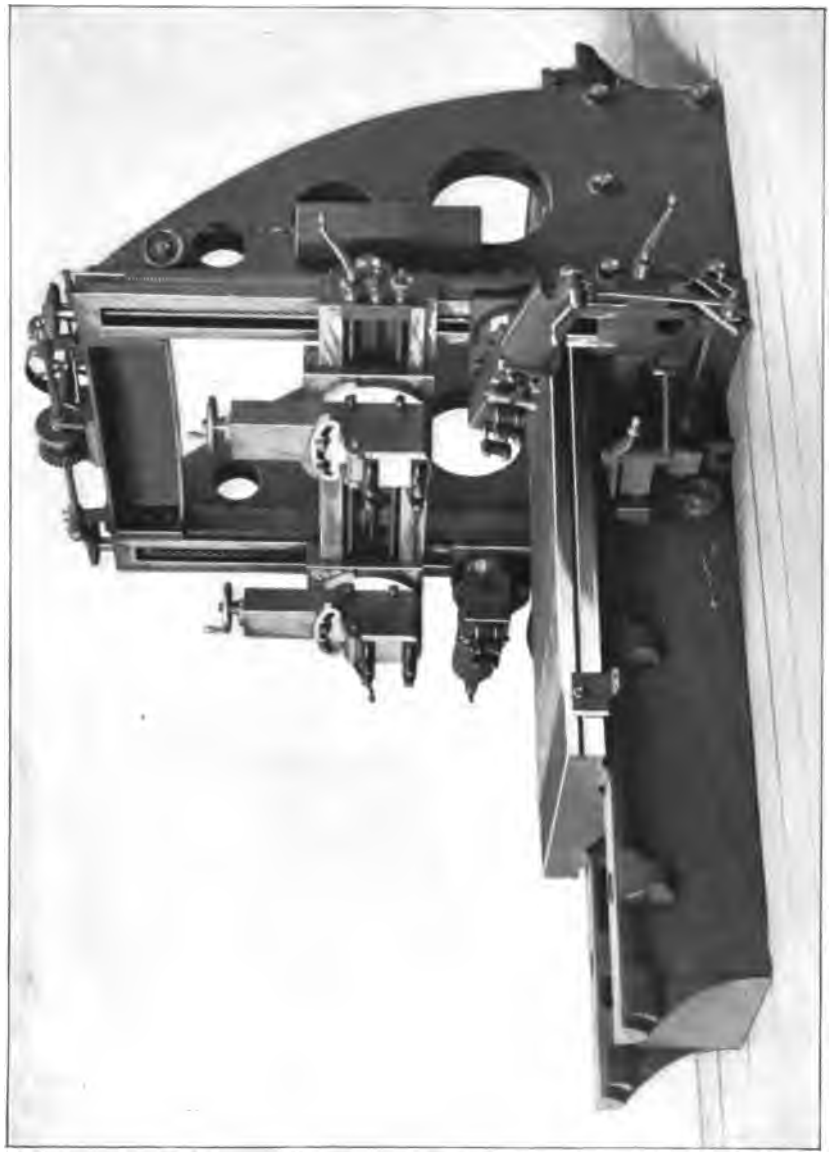
The origin of subsequent applications of tool multiplication seems to have been the Whitworth duplex lathe rests. This was an important departure, the developments of which have extended to nearly all heavy lathes. The advantages are greatest in two cases, one being that in which the work is very long and the other in which it is of large diameter. In pieces of moderate length and diameter the single tool answers very well. But with a very long traverse, or a large diameter, the proportion which the actual cutting bears to the number of lineal feet revolved per minute is so immeasurably small that the multiple principle must be introduced if the wages item is to be kept down. The result is that we have the shafting



A DUPLEX RAILWAY WHEEL LATHE FOR 8-FOOT WHEELS, WITH FOUR COMPOUND, SELF-ACTING SLIDE RESTS, MOVABLE LONGITUDINALLY AND TRANSVERSELY, AND EACH CAPABLE OF INDEPENDENT ACTION. WEIGHT, 40 TONS. MADE BY MESSRS. JAMES SPENCER & CO., HOLLINGWOOD, MANCHESTER, ENGLAND

in these directions. But though the reciprocating tools are at an obvious disadvantage for shaping large numbers of small pieces, and especially pieces of irregular section, they are far too useful lathes and gun lathes in the one direction, and the face lathes for turning and boring in the other.

In the shafting lathes three tools operate, two at the front and one be-

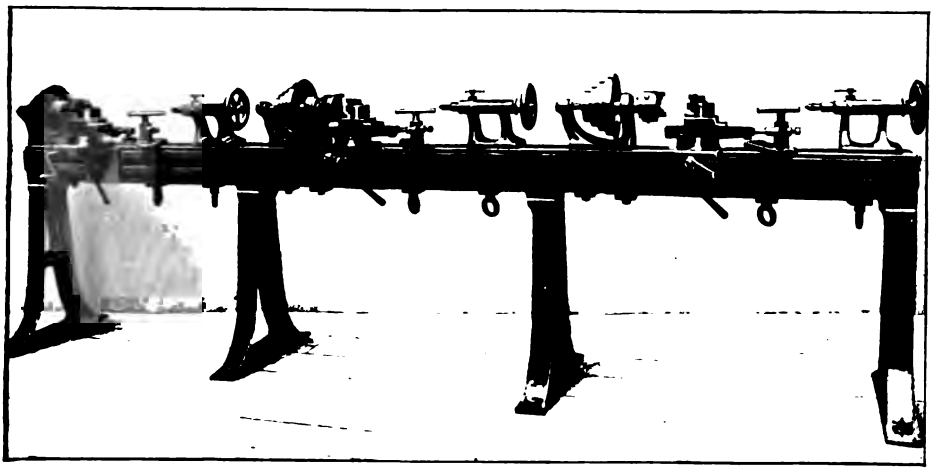


A SIXTY-INCH PLANER WITH FOUR TOOL BOXES, BUILT BY THE NILES TOOL WORKS CO., HAMILTON, OHIO, U. S. A.

hind, three compound rests being carried on one saddle. Gun lathes combine provision for the simultaneous action of four tools held in as many tool slides on two carriages, each of which is independent of the other.

Railway work affords numerous examples of duplication of tools. Double axle-lathes are used for turning both ends of a locomotive or carriage axle at the same time. The axle is supported at each end on the centres of sliding heads, and is driven by a geared central headstock, while the cutters in the slide rest act simultaneously. Even for the minor operations of cutting off and centring railway axles, preparatory to turning them, double-ended machines are used. The axle is revolved in two self-centring jaws giving changes of speed which can be accelerated as the tools approach the centre. After the ends are squared down, the holes are drilled by centring heads operated by a lever. Double-ended machines are also made for centring alone.

Wheel and tire lathes are mostly duplex. Carriage wheels are turned and bored on machines having two face plates, ranged either side by side or back to back. Wheels on their axles or wheel tires are turned on double lathes in which the chucks face towards each other, and the tool rests are double. In the American double car-wheel lathes two broad tools are used, each covering the entire width of a wheel tread, the latter being turned while the wheels are on their axles. To resist the stress of such heavy cutting the lathes are constructed with short, stiff rests. The wheels are each clamped in three places, and the axles also in three places, close to each wheel, besides being centred, so that there are in all fourteen points of support to resist the stress of two broad tools operating simultaneously.

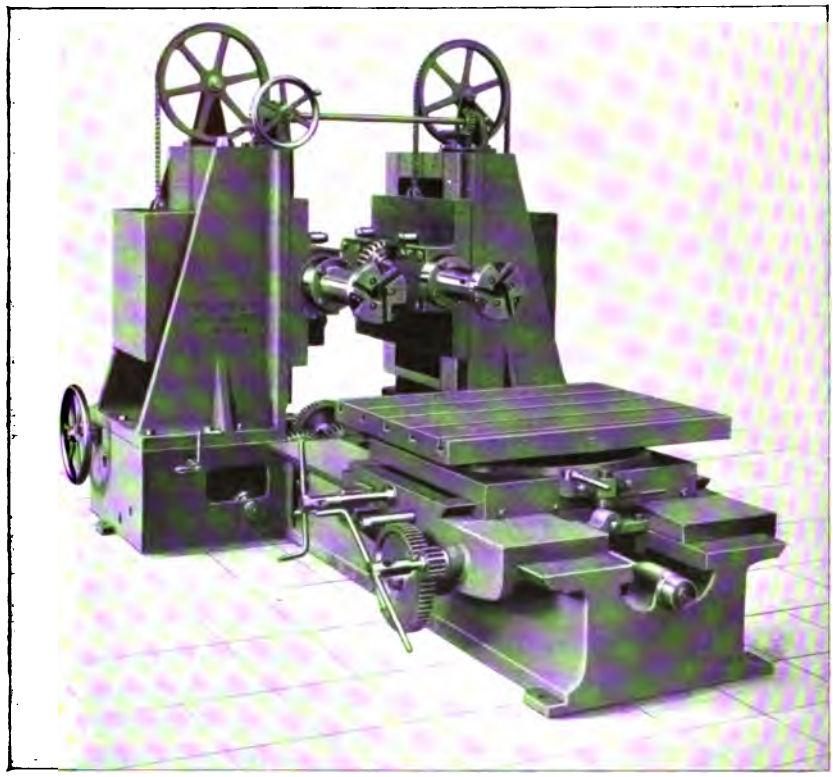


A TREBLE LATHE FOR BRASS FINISHERS AND ELECTRICIANS SIX INCH CENTRES AND 12-FOOT BED. BUILT BY MESSRS. JAMES ARCHDALE & CO., BIRMINGHAM, ENGLAND

Surfacing lathes have two rests on a movable slide bed, and some have a capstan rest in addition. The base-plate lathes are also fitted with duplex rests.

The vertical boring and turning mill is a now familiar example of a duplex face lathe, but with all the advantages which result from having the work supported on a horizontal table during adjustment and while cutting.

Some pulley-turning lathes have six tools operating at once, so that the outer and inner faces are being turned and the hole is bored at the same time. Others are designed with two heads which move on a horizontal bed towards the work, centred by its bore on a vertical arbour. Each head has a holder to



A DUPLEX BORING MACHINE WITH ADJUSTABLE SPINDLES FOR CYLINDER AND PUMP WORK
BUILT BY MESSRS. WM. MUIR & CO., LTD., MANCHESTER, ENGLAND

carry two tools. Pulleys can be turned with parallel or with crowned faces. Machines for facing and turning the edges of the flanges of pipes, valves and cylinders are made duplex, the work being attached to a central table and the spindles in the two heads operating in unison at opposite ends. The double-head lathe employed for turning the plugs of cocks is a special case comprising two complete lathes on one bed. The plugs are generally roughed out on one set of centres and finished on another by one attendant. The practice of fitting two and even three lathes to one bed in charge of one man is also followed in general work.

Though the duplex rests have been so long known and used, only a small minority of common lathes have them at all. But the turret lathe now renders them unnecessary on small lathes, and it might be applied to many of these as an alternative to the ordinary slide rest. It is not utilised in that way quite so much in Great Britain as in America. It is more convenient, however, when fitted to its own slide on the bed. A good deal of work is usurped by the turret lathe which was formerly done on the common one

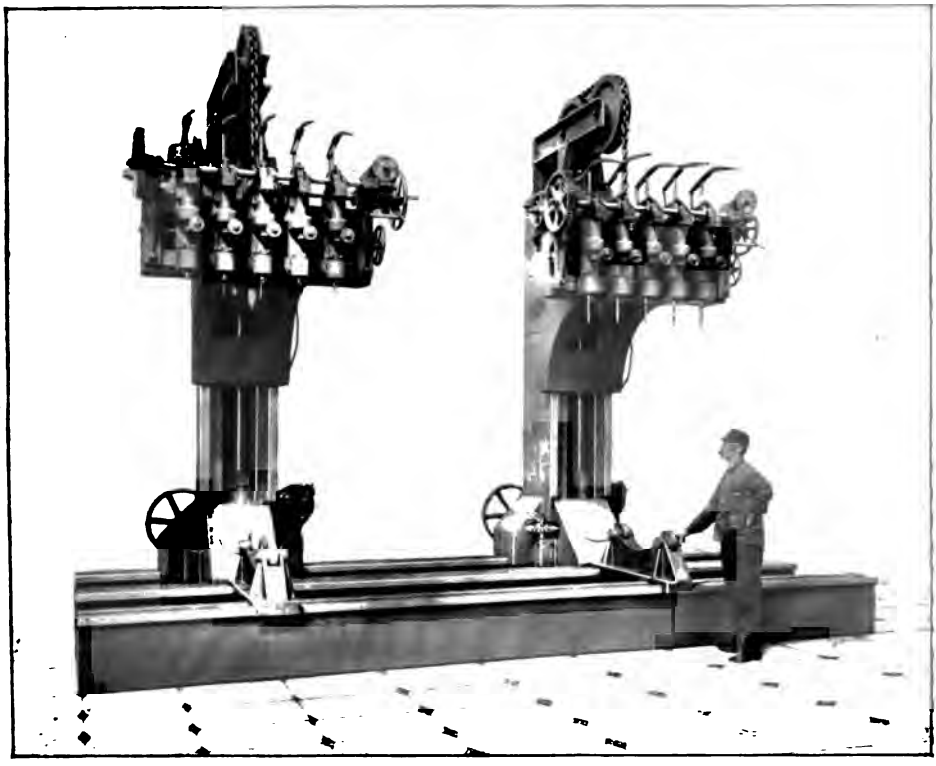
In this type, therefore, we have one of the most complete applications of the principle under consideration. Single cutting tools are set, each in its hole, and duplicated; tools are also held in a box or holder secured in the turret and brought round in succession. These sets of tools are adapted to fine-gauged work, because the latter is supported by vees opposed to the cutting point. They rough, finish, screw, knurl, produce rounded ends, and some of them perform the work of several lathe tools.

This compound duplication may be repeated in two or more boxes in one turret, and the turret may hold from six to eight or more separate cutting instruments, ranging from simple to complex types, each ready for immediate duty.

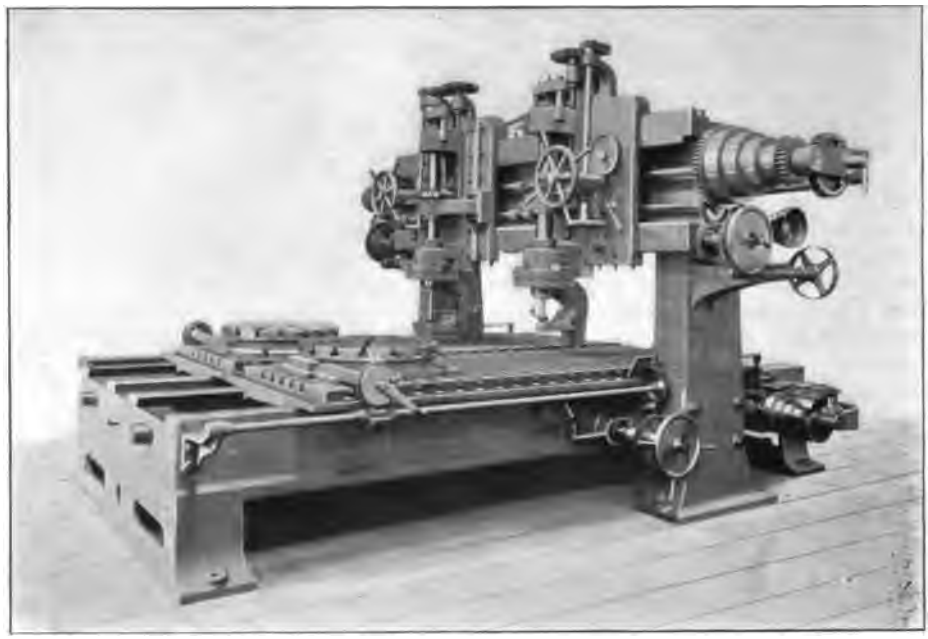
Supplementary rests on the cross slide are also fitted to contain tools for cutting off, knurling, and for forming irregular outlines, each in a single operation. The addition of a turret to the cross slide of a lathe already fitted with one on the bed is now adopted in a few instances. The turret is usually square and carries four tools for turning, forming, knurling, cutting off, etc.

We have many turret lathes, but hitherto they have been designed mainly for special work. The present tendency is to employ them to a greater extent than they are yet for the general repetitive work of a shop, for castings and forgings of many shapes and varying widely in dimensions. In time many jobs which now go to a common lathe to be operated on according to the particular ideas of the turner,—using single tools,—will be done in special lathes with an array of tools set once for producing a large number of similar pieces. Some of these machines have a formidable appearance, but as far as the workman is concerned their handling is simple enough.

In the boring machines the number of separate cutters increases with increase in diameter. Boring tools with two cutters only soon give place to boring heads in which from three to twenty cutters may be inserted. The simple boring machine, distinct from and more handy than a lathe when rigged for boring, has developed into the duplex machine, having centres capable of adjustment within a range of several inches, and in which the spindles are driven by



A TEN-SPINDLE, ELECTRICALLY-DRIVEN DRILLING MACHINE BUILT BY MESSRS. WM. SELLERS & CO., INC., PHILADELPHIA



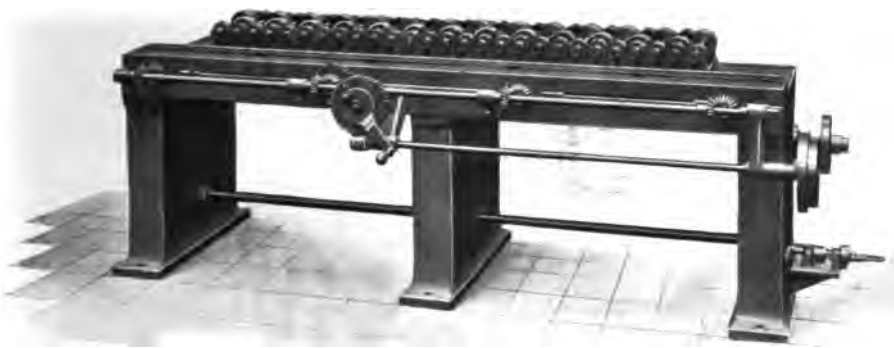
A DUPLEX VERTICAL MILLING MACHINE MADE BY MESSRS. CUNLIFFE & CROOM, LTD, MANCHESTER, ENGLAND. THE TABLES AND HEADS CAN BE RUN EITHER AS INDEPENDENT MACHINES OR COUPLED

means of worm gearing. This, therefore, is an example of duplication of cutting operations, first in the head, and second in the spindles. The types are numerous, including machines suitable for miscellaneous work and those for special service. Thus spindles are driven in unison or independently. Centres are adjustable for general work or fixed for special and standard work.

In one type of machine the work table or platen and the spindle headstock are carried on a bed and standards similar to a lathe bed. The table, with the work attached, is bolted down, and the spindles traverse with their headstock. One spindle has power of adjustment for varying centres. In another example a planer type of bed and table are flanked at one end with uprights that carry the spindle heads, one of which has capacity for adjustment. In another type, which has but one spindle for cylinder boring, a second head is arranged transversely at right angles, for boring the crankshaft bearings at the same time. Facing arms for facing flanges and turning their outside edges are added.

For heavy cylinder-boring the tools in the facing arms are often duplicated, an arm being double and provided with compound tool slides. Four facing tools can thus be operated at once on two flanges when a couple of such arms are fixed on the bar. The spindles of horizontal boring machines are made with fixed centres to suit standard engines and pumps, two, three, or four spindles being thus fixed. A good many of these machines have been made for the duplex steam pumps and for street car frames. In a good example of multiplication of boring spindles the work is carried on a stationary platen situated nearly centrally on a long bed, and two boring heads are adjustable on the bed towards and away from the work. Each head carries two spindles having adjustable centres, and each has independent driving and feed arrangements, so that four operations of drilling or boring can be carried on at once and at different or the same centres.

There are no machine tools of the strictly single edged type in which multiplication is carried to so great an extent as in the drills,—none in which such great variation exists in design as a direct result of increase in number of spindles. This is an advance on the practice of arranging several similar machines in line under the charge of one man still adopted for some purposes. Many multiple drilling machines, as well as those with single spindles, are also used for tapping subsequently to drilling, the work remaining fixed and the centres unaltered,—a device which is adopted both on horizontal and vertical machines.



A TWENTY-SEVEN-SPINDLE HORIZONTAL DRILLING MACHINE MADE BY MESSRS. JOHN HETHERINGTON & SONS, LTD., MANCHESTER, ENGLAND

The most familiar example of multiplication exists in the light, sensitive, high-speed machines with spindles varying from two to eight and upwards, all driven simultaneously by a continuous belt, the tension of which is ensured by the use of a tightening pulley. By this arrangement each spindle runs at a uniform speed.

Passing to heavier types, in one broad class an oblong table is supported between two uprights underneath a cross slide which carries the spindle heads. Variations are made to accommodate every kind of work. The number of spindles usually ranges from two to eight, being made in the heavier machines to drill holes to about 3½ inches in diameter. Among special machines for railway work are those having two spindles for drilling both ends of the connecting and coupling rods of locomotives at one time within a range of from about 3 to 10 feet. Rails are drilled in machines having either two or three spindles operating at once, the centres being adjustable within a range of from 4 to 12 inches. Each spindle may have a separate vertical adjustment to compensate for the unequal wear of drills. The links of the American pin-connected bridges are also drilled in two-spindle machines, each mounted on standards, the centres of which are adjustable along the bed. There is another type of machine used only for drilling brake levers, flanges, bridge work, and such like, having capacity for adjustment of centres only. The usual method of driving is through spiral gears, a pair of gears operating each spindle from a horizontal shaft. The work table is in some cases fed upwards to the drills. But even here there are many differences in design. Some special machines for platers and boilermakers are capable of drilling holes up to 100 in number at once, the spindles being adjustable for pitch within a moderate limit.

The work of boiler making has been the occasion of the development of several multiple machines for shell seams, butt straps, and flue rings. In one of the best types used for shells three vertical standards each carry several drill

A SIXTEEN-SPINDLE DRILLING MACHINE MADE BY THE BAUSH MACHINE TOOL CO., SPRINGFIELD, MASS., U. S. A.

spindles, each standard having a radial movement on its own slide bed. The machine is rendered adaptable to a wide range of work by making one slide bed to radiate through an angle of 60 degrees, by which its spindle can be brought opposite to one of the others. The butt-strap drilling machines comprise a single upright on a base, carrying from three to six spindles, adjustable for centres. The boiler flue flange drilling machine is a special adaptation of a vertical-spindle drill. The flue is carried on a rotary horizontal chuck and turned round and adjusted for pitch by change wheels. Two holes are being drilled on opposite sides of a pair of abutting flanges, with a calking ring between. The same machine countersinks.

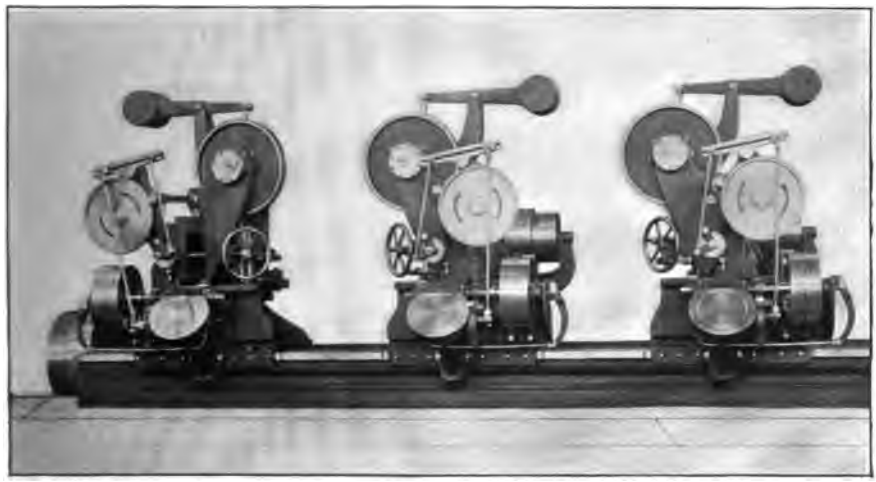
In another class of machine the special requirements of double ended work, such as pipes and engine and pump cylinders, are embodied. Two sets of horizontal spindles are arranged on carriages at each end of a long bed, each head being adjustable, so that the flanges at each end of a pipe or cylinder can be

drilled simultaneously. A special instance is that of a three spindle drill in which the centre spindle is fixed, while the two flanking ones slide on faces situated at an angle of 60 degrees, with the result that the circle is always divided equally into three parts. When these are adjusted at equal distances from the stationary one the centres will be alike round a curve. Three holes can be thus drilled at one time in a cylinder cover.

There is a very large class of multiple drilling machines in which the drills are arranged in movable groups instead of in line, and in which all are operated from a central main spindle, their adjustments for centres being readily effected, and driving taking place through universal joints at any centres within the maximum range allowed. The number of spindles varies with requirements. In one class of vertical pillar machines the number may be four, eight, or fourteen. In the eight-spindle depth of work which can be got under such a machine is limited to about 4 feet in this size, and other sizes in proportion, horizontal machines are made in which the piece to be drilled is placed on a bed and the spindles are operated horizontally.

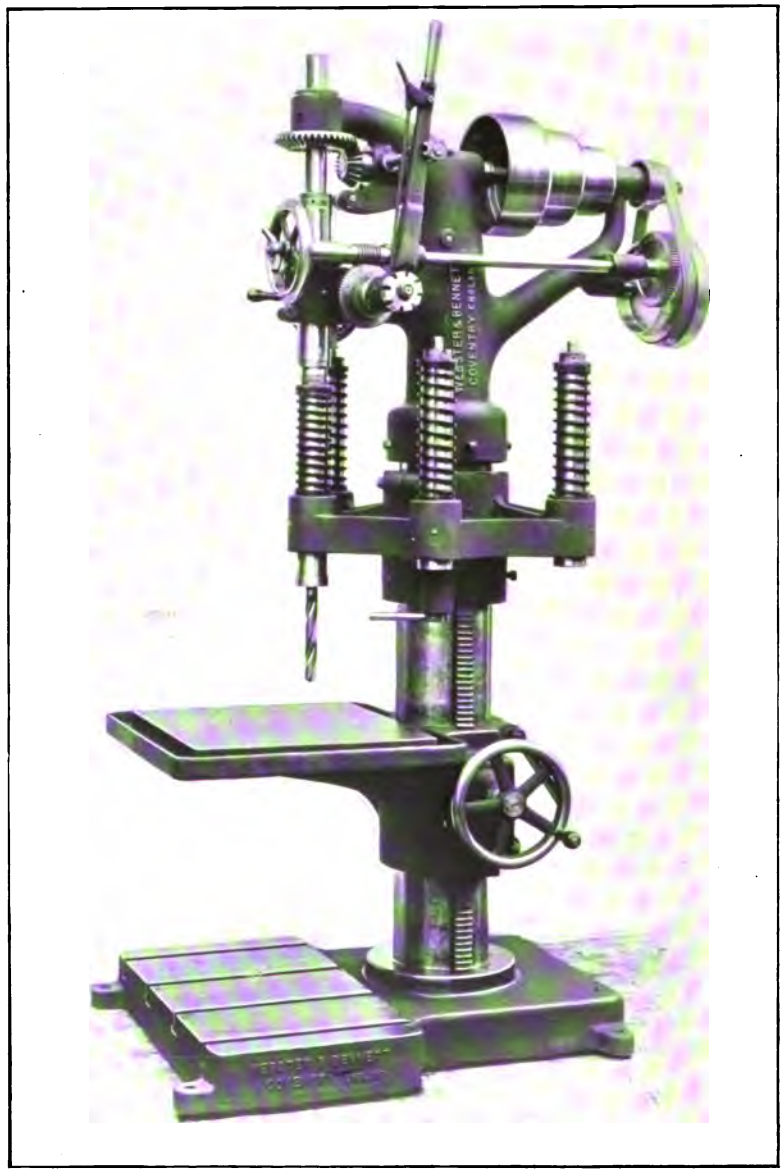
Some turret drilling machines are made with from three to twelve spindles to the turret, to carry drills, reamers, tap holders, and other tools. Although but one tool operates at one time, the advantages are as great as in the turret lathe, because time is saved that would otherwise be spent in changing tools.

We have become so accustomed to good screwing machines that we are apt to forget the time when none were in existence and when every screw was cut either in a lathe with a single "vee" tool, or with dies that squeezed and scraped, but seldom cut. The screwing machines multiplied the cutting edges. The dies themselves are tapered and backed off, and the result is that a screw



TRIPLE-HEAD SLOTTING MACHINE FOR LOCOMOTIVE FRAMES, EACH HEAD DRIVEN AND FED INDEPENDENTLY AND CONTROLLED FROM ONE POSITION. BUILT BY MESSRS. BEMENT, MILES & CO., PHILADELPHIA, U. S. A.

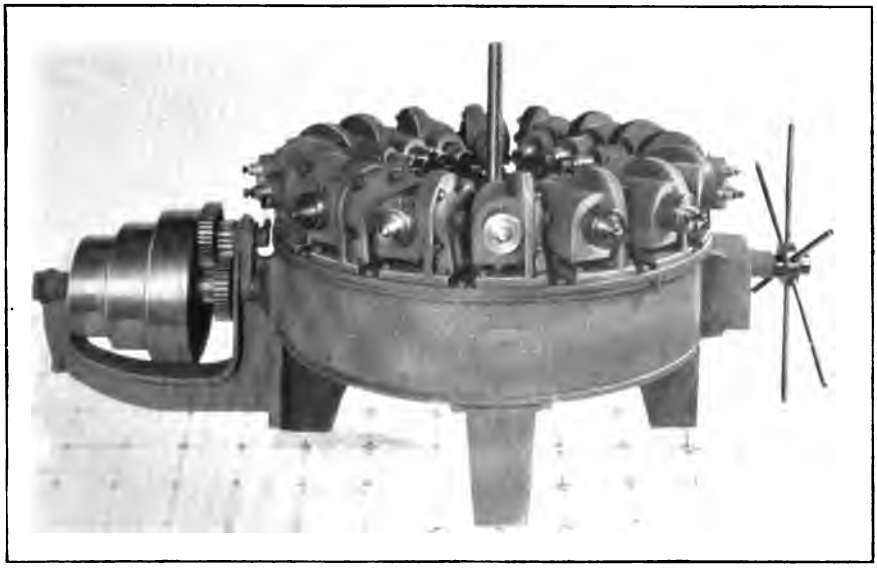
set the smallest circle of drills is 5 inches in diameter, the largest possible, 18 inches in diameter, so that circles of eight holes within these ranges can be drilled in the same time that would be required for a single hole. As the can be cut with a clean, full thread to gauged size at a single traverse. Three or more dies, each with several teeth, cut at once; they are adjustable simultaneously, and they are not run back over the screw just cut, as in the old



A SIX-SPINDLE TURRET DRILLING MACHINE MADE BY MESSRS. WEBSTER & BENNETT, COVENTRY, ENGLAND

machines, but are released instantly. In the pipe screwing machines four dies and upwards are used. When, in addition, machines are duplicated on one bed, the economies are further increased. Two are often mounted thus, in the care of one attendant, or a capstan rest for several tools is added to the common chasing lathe.

The production of cheap bolts would be impossible if the cutting tools were not multiplied on all the machines by which they are produced. They are

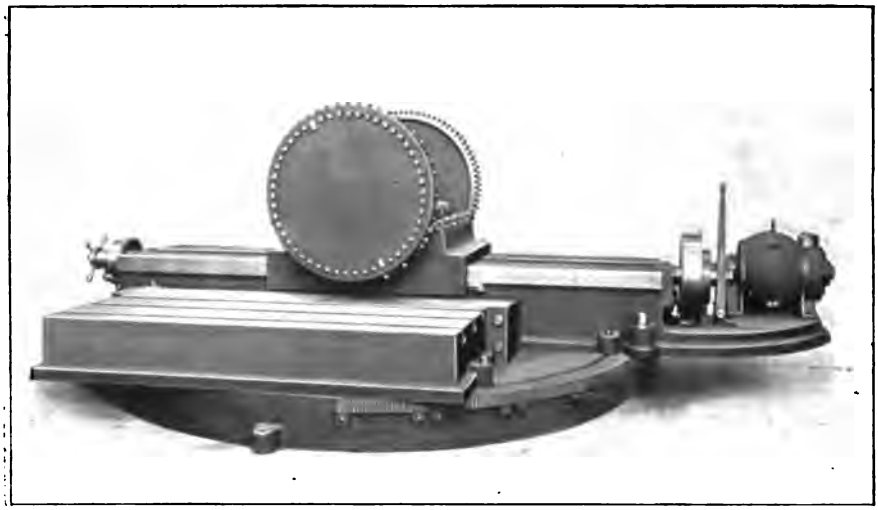


A SIXTEEN-SPINDLE HUB DRILLING AND TAPPING MACHINE MADE BY MESSRS. KEARNEY & TRECKER, MILWAUKEE, WIS., U. S. A.

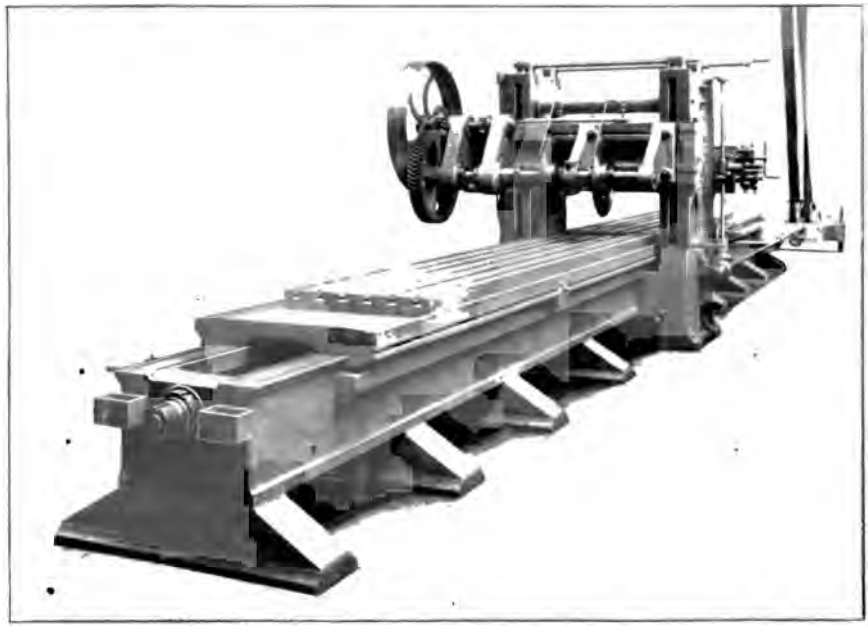
turned and screwed on the chasing or the capstan lathe at the rate of 1000 or more a day; their nuts are drilled and tapped on machines having from two to six spindles, operating on as many different nuts at once. They are shaped or milled on opposite faces at one time. When shaped, the slotting machine may have a double tool holder for cutting four faces of two nuts at once, and nut facing milling machines are duplicated with the same result.

The milling machine affords the best example of the multiplication of cutting tools in the modern shop, though in a different sence from that of the drills. These are a case of simple single edged tools duplicated; the milling cutters, on the other hand, are single tools with many edges. A milling cutter may have twenty or thirty or more distinct cutting edges, and, if ground properly, each will do its proportion of the work. Each edge is a distinct tool, whether in a solid body, or, more obviously, when teeth are inserted. Each is as truly a separate tool as the cutters in a boring bar or the chasers in a screwing die head. The gain obtained by the use of these cutters is not directly in proportion to the number of their teeth. It is not possible to make, say, twenty of these cutting edges do the work of twenty distinct single-edged tools, since their power of penetration is not nearly sufficient. But with ample lubrication a milling cutter may be expected to do about three times as much as a single-edged tool. Though the penetration of a single edge is slight yet there is great advantage in being able to tool a broad surface at a single traverse.

The point, however, to be noted is that the use of these cutters has an immense result in economy in the machine



A ROTARY PLANER MADE BY THE NEWTON MACHINE TOOL WORKS, PHILADELPHIA. DRIVEN BY A MOTOR MADE BY THE SPRAGUE ELECTRIC CO., NEW YORK

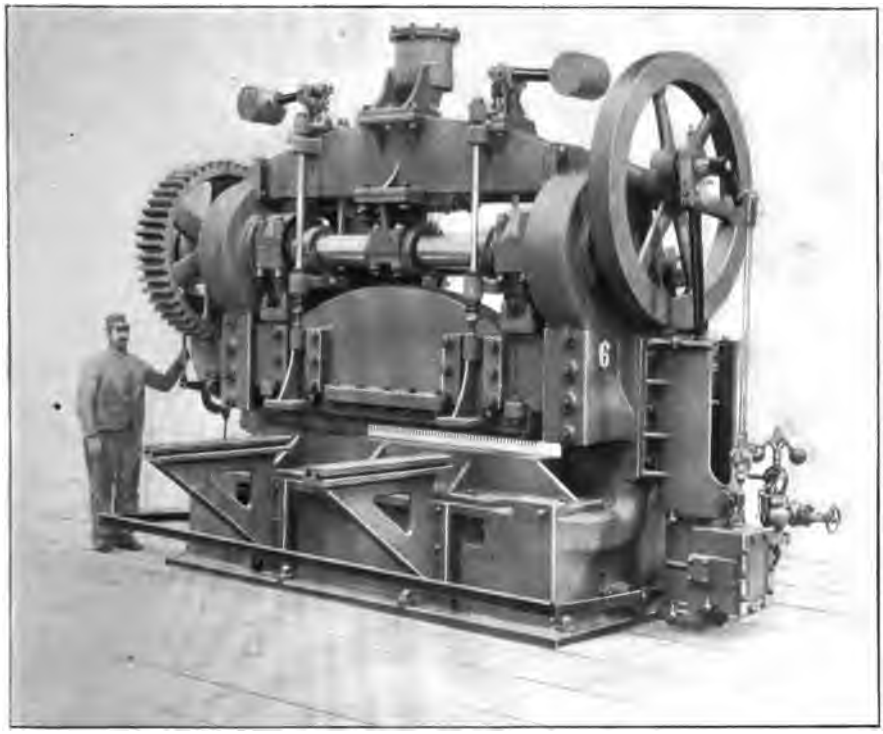


PLANING, MILLING AND SAWING MACHINE. ONE CROSS SLIDE CARRIES MILLING CUTTERS OR SAWS, AND THE OTHER, TOOL BOXES FOR PLANING. MADE BY MESSRS. JOHN HETHERINGTON & SONS, LTD., MANCHESTER, ENGLAND

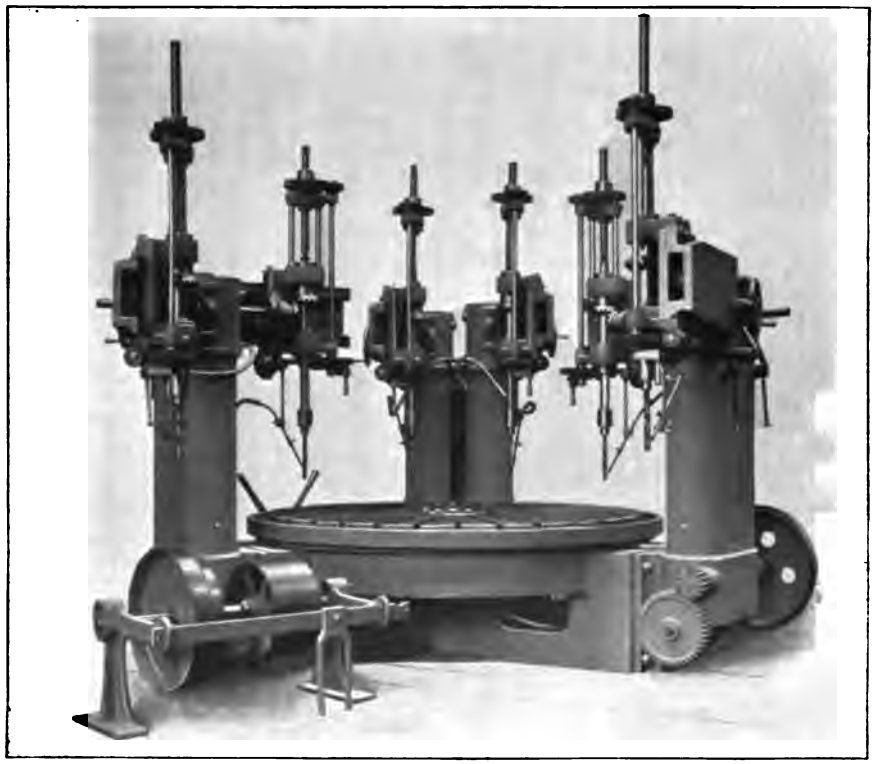
shop, due not alone to the multiplication of cutting edges, but also to the facilities which they afford for tooling all imaginable profiles which would otherwise have to be shaped laboriously, and not so accurately, by other methods There is no process which can compete with that of milling when irregular outlines have to be formed. The profile mills which have the same section as that of the work they have to shape will effect, in one or two traverses, results which could be otherwise obtained only in a most tedious and imperfect fashion by single-edge tools. The profiling machines, too, in which edges of irregular contour are shaped by cutters guided by a form, are of great value in special cases, possessing advantages unapproachable by any other methods of cutting.

When the milling machine takes the place of the planer in operating on plane surfaces of large area, the planer duplication of tools becomes embodied, and so we have two, three, or four separate spindles. Two are set vertically, slide on an overhanging arm, as in the open-sided type of milling machine, or two horizontal spindles are opposed to each other when the type is that of a planer bed and side standards; or two, laid horizontally, slide on standards, and either one or two vertical spindles on a cross rail, as in the most complete planer type, in which two pieces can be milled on top and outside faces at once. Each separate spindle then has full power of adjustment in, and with, its head, and either face or edge mills can be used.

Double spindle machines of the profiling type are used to a considerable extent, just doubling the capacity of a machine with the same attendance. The spindles range from 1 ½ to 4 inches, the heavier tools being constructed on the broad outlines of heavy planing ma-



A MULTIPLE PUNCHING MACHINE MADE BY THE HILLES & JONES CO., WILMINGTON, DELAWARE, U. S. A. THIS MACHINE WILL PUNCH 100 HOLES AT ONE STROKE



A MULTIPLE-ARM RADIAL DRILL BUILT BY MESSRS. BEYER, PEACOCK & CO., LTD., MANCHESTER, ENGLAND

chines, with bed and table, uprights and cross slide adjustable vertically, and spindle heads adjustable horizontally.

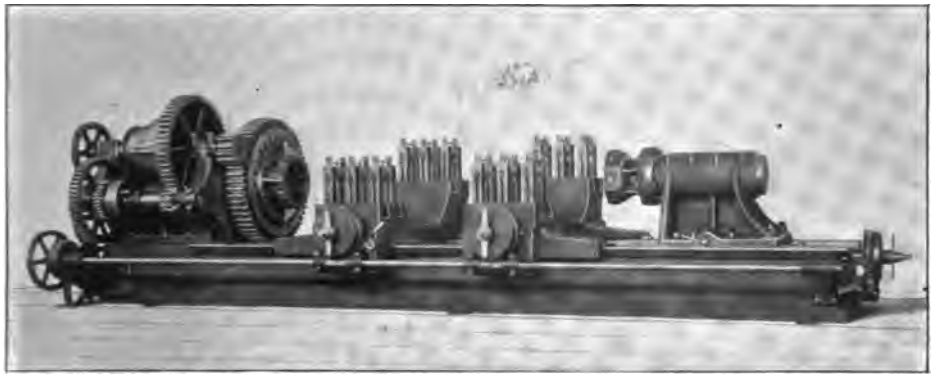
The rotary planer is an excellent example of multiplication of tools. Discs are used up to as much as 7 feet in diameter. Each tool point, of which there are several dozens in the larger sizes, is held in place with a setscrew, and each is a true cutting tool, fixed at an angle corresponding with that of top rake. There is nothing so economical for facing large surfaces in cast or wrought metals. It is used for the feet and tops of standards, for the ends of columns, the ends of girders, the edges of armour plate, and much else.

The arrangements of these machines are varied to suit demands. In their broad designs they are either horizontal or vertical. Essentially the first design comprises a bed to which the work is bolted, and a tool head, one or the other of which traverses. One modification is adopted for facing off the ends of long pieces of work to an angle, as more convenient than swinging the work itself, especially in a shop where space is limited. Rotary planers are mounted on vertical framings fitted in very much the same style as slotting machines, the head being adjustable vertically and the work carried on a circular table beneath. In horizontal duplex rotary planers the heads traverse on their beds, which movement gives the length of surface which can be operated on, and one bed is adjustable towards or away from the other. Each head can be operated independently of the others. Fitting two discs doubles the economy, until there will be in some cases a hundred tool points cutting simultaneously on one piece of work.

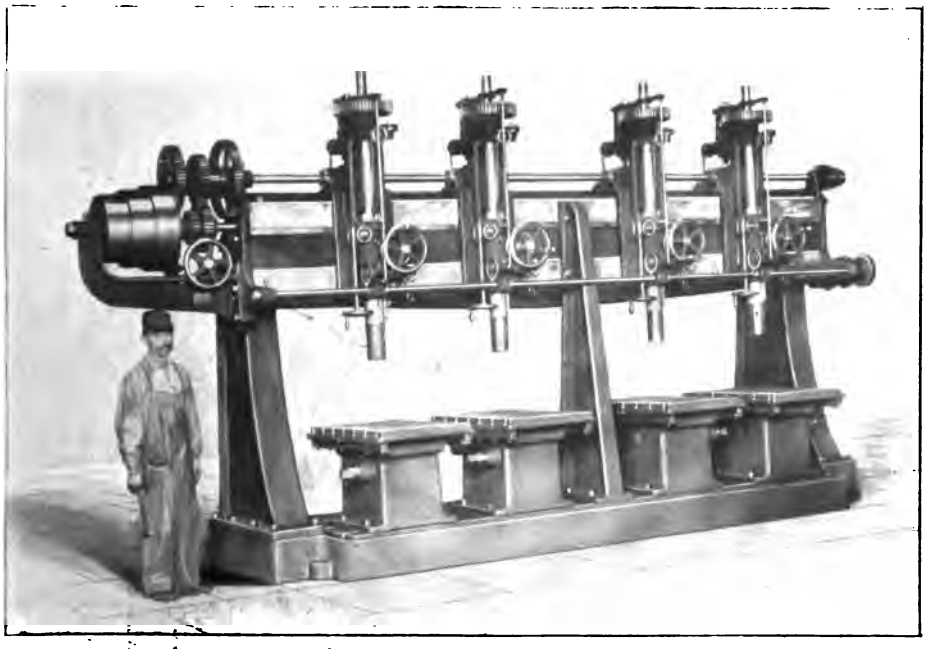
Gear cutting when done with rotary tools is a department of milling. Cut-

ters are multiplied in producing spur and rack gears in two ways, either by radial cutters, to suit any given size of wheel and to shape two or more teeth at once, or by gangs of cutters for racks. In the special rack cutting machines the cutters are multiplied from two up to a dozen in some cases, representing the number of teeth cut at a single traverse. As several racks can be shaped simultaneously, the economy is great.

In cycle work there are many examples of multiplication. For sprocket milling double centres are often employed, and two cutters on a single arbour shape the teeth,—not in two sprockets only, but in two rows simultaneously. In the formation of cycle



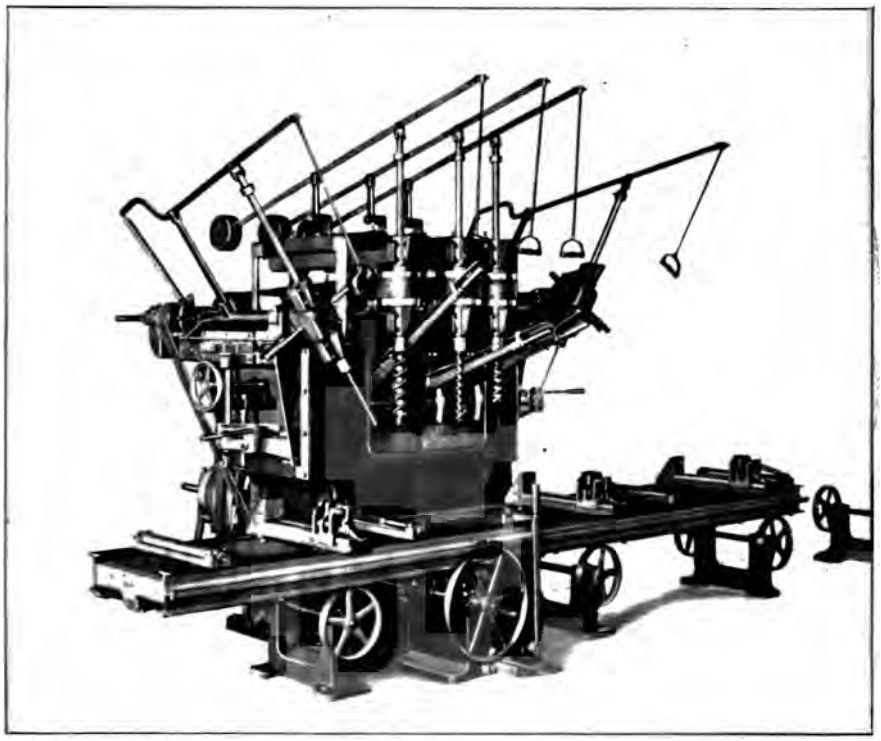
A LATHE FOR SLICING OFF STEEL DISCS FROM INGOTS PREPARATORY TO MAKING THEM INTO CAR AND LOCOMOTIVE WHEEL TIRES. BUILT BY MESSRS BEMENT, MILES & CO., PHILADELPHIA, U. S A.



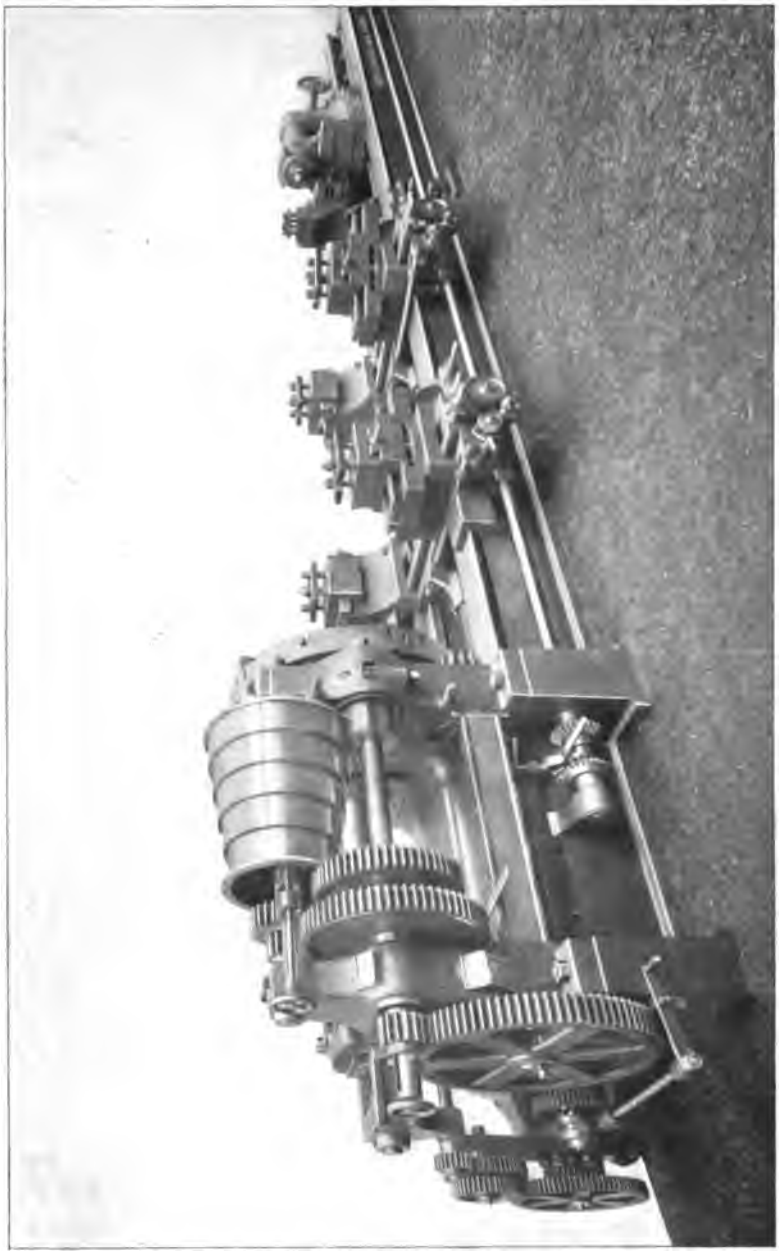
A TWENTY INCH MULTIPLE DRILL MADE BY THE BICKFORD DRILL & TOOL CO., CINCINNATI, OHIO, U. S. A.
DESIGNED FOR DRILLING SIMULTANEOUSLY FOUR 3-INCH HOLES THROUGH
12 INCHES OF SOLID STEEL

A LATHE FOR TURNING MARINE CRANKSHAFTS WEIGHING UP TO 66 TONS. WEIGHT OF LATHE, 440 TONS. BUILT BY ERNST SCHIESS, DÜSSELDORF, GERMANY. THE LATHE HAS SIX TOOL POSTS, TWO HEAD STOCKS, AND TWO FOOT STOCKS, AND IS DRIVEN BY TWO 50 H. P. ELECTRIC MOTORS. ITS SWING IS 11 FEET 8 INCHES, AND THE EXTREME LENGTH BETWEEN CENTRES, WHEN THE RIGHT HAND FOOT STOCK IS REMOVED AND THE OTHER IS SLID DOWN TO THE END OF ITS TRAVEL, IS 78 FEET 7 INCHES. THE EXTREME LENGTH OF THE BED 19114 FEET.

hubs and pedal barrels tools of the forming type are used, the profile of which corresponds to that of the hub or the pedal. Two tools are in use on opposite sides, one roughing first, the other coming in to finish. The bottom brackets of cycle framings are bored simultaneously by drills of which the spindles can be adjusted to suit brackets for various framings. Light multiple machines are used for drilling the hubs of cycles in two operations,—one-half the holes being drilled each time,—the relative accuracy of the sets being ensured by a fixture and stop. The two spindle drilling machines for the rims of cycles are special adaptations, in which the spindle heads are adjustable both for pitch and angle. Machines which operate on both ends of a cylindrical body at once are much employed in the cycle trade. Here we find the double turret machines for hubs, pedal barrels and crank axles, which are chucked about the centre in a circular headstock situated centrally on the bed. Each turret then operates on its own end and in unison. Duplex machines are used in which two sprocket wheels are held at one time, and one face of each is finished at one operation, besides which the hole is rough-bored and the rim rough-turned. There yet remain several examples of multiplication which stand very much alone in the sense of not admitting of classification under any of the previous types. The broad forming tools now used for turning small handles of many shapes, knobs, pillarets, brass cocks, and kindred articles are, though in one piece only, an illustration of multiplication. For, instead of an irregular profile being turned by a single pointed traversing tool, its whole width is cut at once without any traverse. When the work is cast or forged nearly to outline,



A FIVE-SPINDLE CAR BORING MACHINE MADE BY THE J. A. FAY & EGAN CO., CINCINNATI, OHIO, U. S. A.

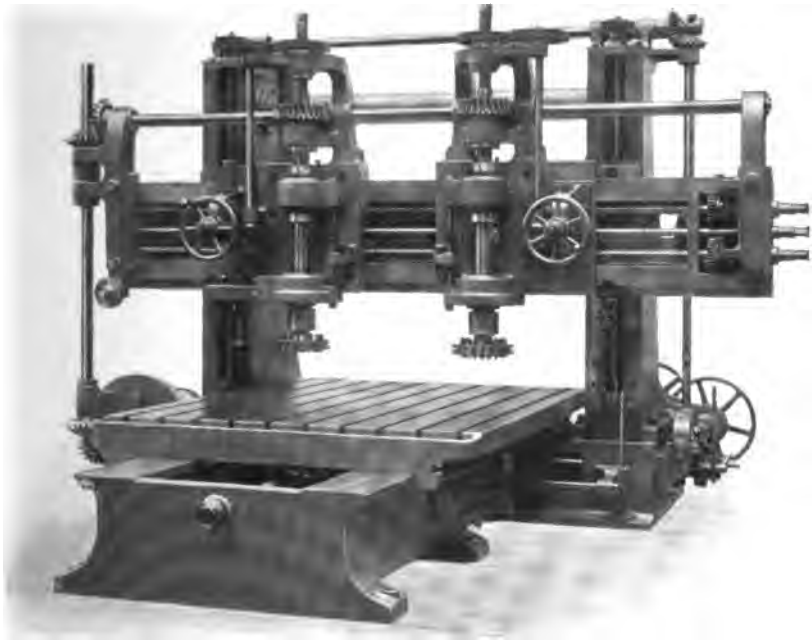


A LATHE FOR PROPELLER SHAFTING AND GUN TUBES BUILT BY MESSRS. LOUDEN BROS., JOHNSTONE, NEAR GLASGOW

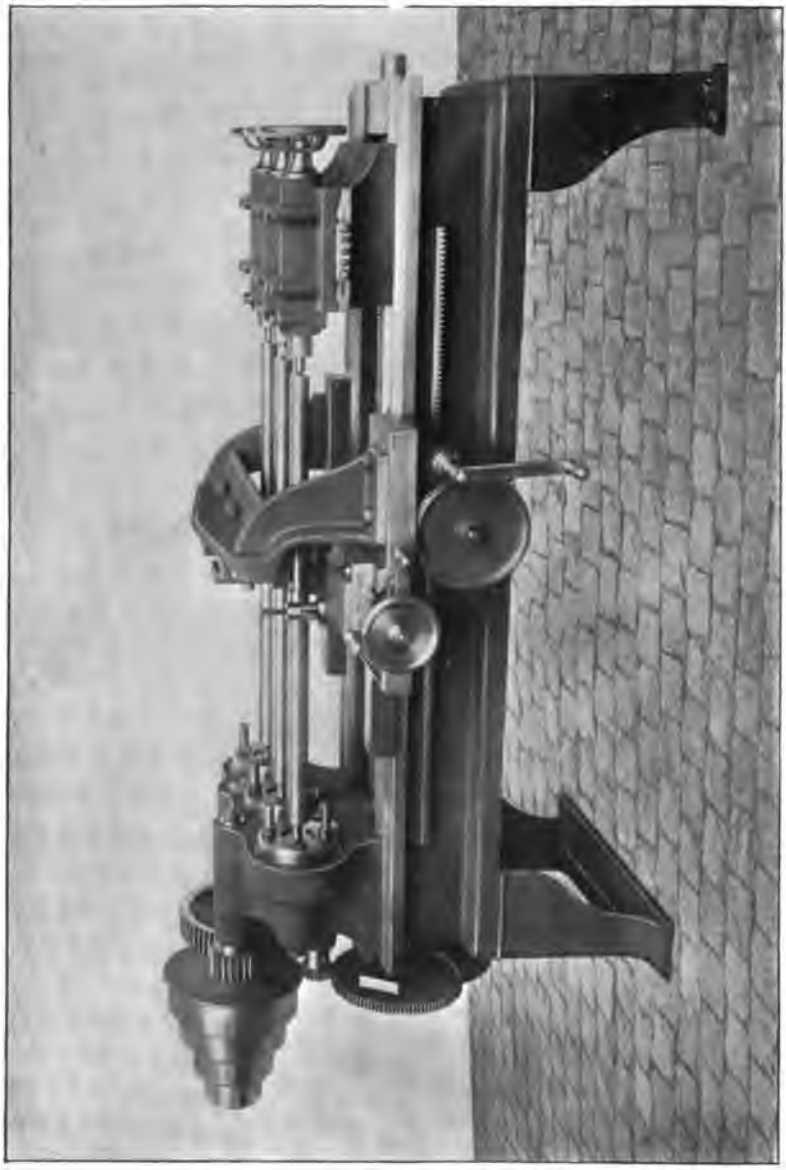
a single cutting stroke will finish the entire profile to exact dimensions.

Some of the key-seating machines of the saw-tooth type afford an illustration of multiplication of edges. They take the place of the single-edge slotting tool, with the result that instead of a large number of strokes being necessary, a few passages of the cutter bar suffice to take out a keyway of moderate dimensions.

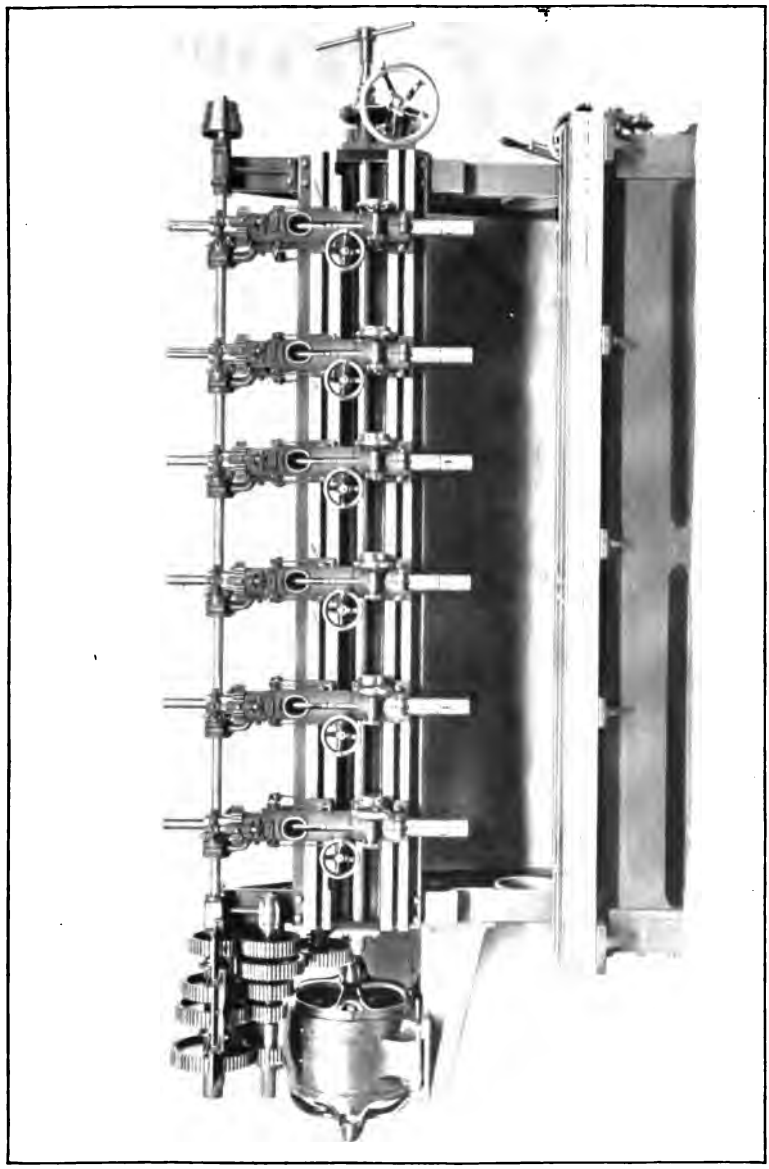
Cutting-off cold saws are duplicated for the purpose of sawing off short shafts or railway axles to exact lengths. One head is fixed, the other adjustable. The saws run at fixed centres, the bars being clamped in vises and fed up to them. In the case of one builder this design has been extended to a six-saw machine, each one being independently adjustable. The heads in this case are fed, are stopped, and returned automatically. The range of length permits of cutting off from 2 to 5 feet in length. A punch,—the spiral type excepted, —is not strictly a cutting tool. Though it acts by shearing, we may waive that strictness of definition in the present instance and note how it is multiplied. The multiple punches, arranged in line, and having centres variable for bridge and girder work, are well known. But many machines are made for operating on structural work with the punches and bolsters arranged to suit special requirements. Thus, one well-known make of machine will punch fifteen ¾ inch holes in a ¾-inch plate to any arranged pattern. In the gate punching machines the number of holes is hardly limited. They often number as many as 100. As the strain of punching in unison would be so great, they act in quick succession, being set on a slope. Machines are duplicated for shearing off angles, the slides being driven diagonally, so that there is ample room to work, and each slide or plunger is independent of the other. In the field of woodworking machinery the



A PLANER TYPE MILLING MACHINE WITH TWO VERTICAL SPINDLES, BUILT BY MESSRS. HULSE & CO., MANCHESTER, ENGLAND



1.—A THREE-SPINDLE LATHE BUILT BY THE ATELIERS DEMOOR, BRUSSELS, BELGIUM



AN ELECTRICALLY-DRIVEN GANG DRILL MADE BY THE PRENTICE BROS. COMPANY, WORCESTER, MASS., U. S. A.

multiple system finds extensive application. The power-driven wood borer is made to bore any number of holes up to a dozen at once. The centres of the spindles are adjustable, as in drills, within certain limits. Spindles are adjusted to bore in line or out of line, all to one depth or to different depths. The feed is imparted to the table by lever and sliding gibbed edges, while its height can be varied. This is one type out of many, and while in some the spindles are horizontal, in others they are vertical.

Circular saws, each saw comprising many edges, are further arranged in gangs containing from two to five saws running in unison. Their value lies in cutting up thick planking into narrow strips of various widths of 2½ and 3 inches and upwards, the saws being attached to adjustable collars which are controlled by levers at the end of the machine, adjusted by an index that shows the width of strip corresponding with a certain position of the lever. The gang saws used for cutting logs into planking are also arranged in series.

It is clear that a rule of very general application is, that when cutting tools are multiplied they must be provided with means for adjustment for centres, or angular relations, or both in combination. These introduce complications and add to cost, but there is no special mechanical difficulty involved therein. The question then becomes one of relative economy,—the balancing of capital and interest against saving in attendance. In some cases there is no question of the economy. Modern boilermaking and bridge and girder construction could not be done without the multiple drills and punches. The cycle could not be sold at a popular price but for the multiplication of tools. Every cheap specialty in manufacture is in greater or less degree a direct result of this multiplication.

Nor does multiplication alone, with its corresponding economy in time, measure the full advantages gained. In most instances a greater degree of accuracy is ensured. Such is the case when work is planed or milled on two or three faces at once without the piece being moved. It is so when the centres of drill spindles are pitched out through change wheels, instead of by the eye and compass of the workman, the only alternative to which is a templet. Especially is uniform accuracy ensured when work is profiled with a formed tool, or with profile milling cutters.

Though much has been effected in increased multiplication of tools during recent years, much remains to be done. Though we cannot see exactly on what lines these developments will proceed, we can be tolerably sure that they will occur, not so much in tools for general service as those for special duty. The modern steel boiler gave occasion to the multiple drill with horizontal spindles; the cycle has been one of the principal agents in developing the modern turret lathe; and every machine or appliance or article of manufacture for which a large demand exists has been the parent of these machines. The tendency of engineering practice is towards increasing specialisation, which is eminently favourable to the multiplication of tools in a single machine, and, therefore, we shall find that the number and complexity of these machines will increase.

ELECTRIC POWER IN THE MACHINE SHOP

CONSIDERATIONS AFFECTING THE CHOICE OF A DISTRIBUTING SYSTEM

By W. M. McFarland

PROBABLY the greatest revolution ever known in human affairs was that caused by the introduction of steam-generated power in the processes of manufacturing. One of the places where it first found application and has ever remained most useful and necessary is the machine shop. The supply of power to the various tools and pieces of apparatus in a machine shop is as essential as the supply of blood to the organs of the human body. Seeing that the supply of power itself is a matter of so great importance, it is to be expected that the means of this distribution will be a subject deserving careful thought and attention.

The designer of a modern machine shop has at his disposal, for power distribution, steam, compressed air, water under pressure, the rope drive, belts and shafting, and electricity. While he may use any of these, all are not equally advantageous and there must be some one that, for his particular purpose, is better than the others. However, when he sets out to determine which one this is, he is often beset with bewilderment. Consideration of the problem is apt to lead at first to confusion, since the advantages of the several systems differ in kind and cannot easily be balanced against one another.

The engineer, studying this subject, has many things to consider besides the mere transmitting of power from the engine shaft to the tool in operation. He must bear in mind, first of all, the profitable operation of the shop. A system of power transmission which, with the same equipment and working force, will enable ten per cent. more work to be turned out than is possible by some other system of transmission, is many times more profitable, although it may cost more to install.

Again, a system of transmission which will permit the erection of cheaper buildings, their easy and convenient extension with the growth of business, or one that will allow of an arrangement of tools advantageous to increased output by giving a logical sequence to the different shop operations, is worthy of the most careful consideration, even in the face of old and tried methods. In any specific case the prevailing conditions must be carefully studied and the decision made after an intelligen weighing of details, although in certain cases the advantage of one or the other system may be evident at once.

In considering the most prominen characteristics of the various methods of power distribution, steam, compressed air, water under pressure, and the rope drive, each having only a limited application, will be discussed but briefly. Power distribution by steam over a considerable area involves long lines of piping and in most cases small and inefficient engines requiring much care. The difficulty of long steam mains may be avoided by placing

AN ELECTRICALLY-DRIVEN PUNCHING AND SHEARING MACHINE, INSTALLED BY MESSRS. ERNEST SCOTT & MOUNTAIN, LTD., NEWCASTLE-ON TYNE, ENGLAND

separate boilers throughout the plant, but the disadvantages of such a system in the way of increased number of stokers, inconvenience of handling coal and ashes, etc., are evident and have usually been sufficient to prevent the adoption of the method. A notable instance where this method of power distribution has lately been discarded is furnished by the immense plant of the Palmer's Shipbuilding and Iron Company, Ltd., at Jarrow-on-Tyne. There the equipment of isolated boilers and small steam engines was only recently displaced by a modern central power house with electric power distribution to induction motors. It is hardly necessary to go into a further recital of the disadvantages of power distribution by small steam engines, since their great wastefulness of steam and other disadvantages are well known, and no one now thinks of installing such a system.

Compressed air as a means of power distribution has lately come into favour for certain classes of work. It seems admirably adapted for small

drilling, riveting and chipping tools, as well as being a great convenience for such purposes as cleaning out machinery, sand-blasting castings, operating small hoists, etc. However, it has not as yet been used for the distribution of any considerable amount of power to machine tools and in the face of the great advantages possessed by electricity, it is doubtful if compressed air with its lines of inflexible piping, troublesome reheaters, noisy exhaust, and relatively low efficiency will ever occupy the first place in the machine shop.

Hydraulic power has been found very useful for heavy riveting, punching and similar processes, but rarely for any purpose where continuous power is required.

For the transmission of large amounts of power for short distances and in a straight line, the rope drive is an

A ROTARY PLANER, BUILT BY THE CLEVELAND PUNCH & SHEAR WORKS CO., CLEVELAND, OHIO, DRIVEN BY AN ELECTRIC MOTOR MADE BY THE CROCKER-WHEELER COMPANY, AMPÈRE, N. J., U. S. A.

efficient, simple and inexpensive device. However, the great subdivision of power required in the machine shop makes it unnecessary to give the rope drive further consideration here.

The means of power distribution, so far considered, are practically eliminated from the discussion by their obvious inadaptibility to machine shop conditions and practice. We have two systems remaining, each of almost universal application, and each, under certain conditions, possessing predominant advantages over the other. Transmission by shafting and belting has long been in possession of the field, and many manufacturers are loath to discard it for a system embodying apparatus apparently intricate and expensive, and described in terms uncouth and unfamiliar. However, electricity has shown such decided advantages in the many instances where it has been adopted, that the machine-shop owner is compelled by self interest to consider it and to become, to a certain extent, a student of electrical engineering.

As compared with transmission by shafting and belting, electric driving has great flexibility; it admits of the location of tools with regard to the greatest economy of production; additions to the machine shop may be made at any time and in any direction without disturbing existing equipment; full advantage may be taken of the convenience of overhead travelling cranes and portable tools, and the lighting of the shop is unobstructed by belts and shafts. The building is not subjected to continuous vibration caused by heavy shafting and pulleys; the operative is not hampered in his work by inconvenient belts, and the shop is more easily kept clean and orderly, all con-

STRAIGHTENING ROLLS, BUILT BY MESSRS. CRAIG & DONALD, JOHNSTONE, NEAR GLASGOW, SCOTLAND, DRIVEN BY A 13 H. P. ELECTRIC MOTOR. INSTALLED IN THE SHIPYARD OF MESSRS. R. STEPHENSON & CO., LTD., HEPBURN-ON-TYNE, BY MESSRS. WARREN, BEATTIE & CO., LTD., MIDDLESBORO, ENGLAND

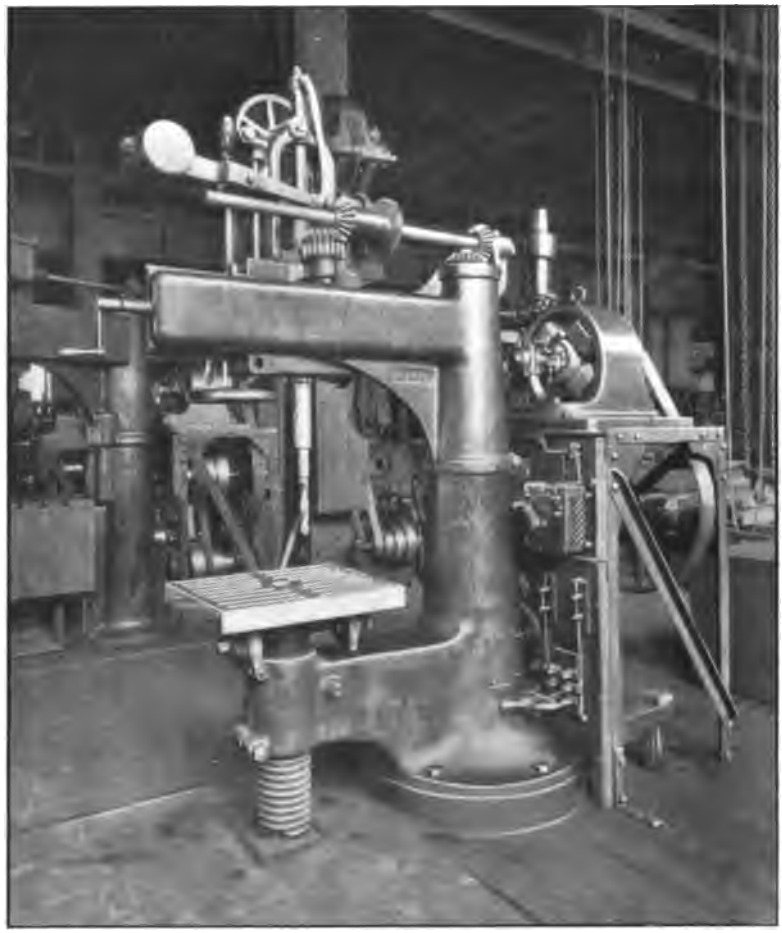
ducive to better and faster work. The subject of the relative energy efficiency of these two methods of transmission is usually dwelt upon, but while the advantages, in this respect, of electric driving are strikingly manifest, the writer believes the matter of power economy to be often of minor importance. If the cost of power in a given line of manufacture is, say, ten per cent. of the whole cost, which is an almost excessive estimate, and a saving equipment, on the other hand, should show an efficiency of from seventy per cent. to seventy-five per cent. It is found that a system of belts and shafting wastes the same amount of power whether any useful energy is being transmitted or not, while with electrical transmission, the efficiency is high even at low loads, and the losses cease altogether when the load is thrown off. Thus, operating a single tool on overtime in a shop equipped with belts and shafting, often

THE INDUCTION MOTOR DRIVING THIS LATHE IS HOUSED IN THE BASE OF THE MACHINE AS SHOWN. MADE BY THE GENERAL ELECTRIC CO., SCHENECTADY, NEW YORK

is made of twenty per cent. of power by adopting electric driving, then the reduced total cost has been by only two per cent. On the other hand, if electric driving, through its greater convenience, flexibility, and other advantages, makes possible a ten per cent. greater output, the matter is well worthy of attention.

However, it may be well to give some of the results arrived at by investigators in this line. Mr. J. J. Flather has collected a large number of instances in which the loss of power in belts and shafting in some of the largest American machine shops varied from fifteen per cent. to eighty per cent. of the power produced. An average electrical means driving the whole outfit, entailing an expenditure of power equal to perhaps half of that required when the entire shop is in operation. Professor C. H Benjamin found that out of twelve shops investigated by him, ten required more horse-power to drive shafting than the average horse-power load on the tools. With the electric drive, on the contrary, only about as much power is generated as is used by the individual tool in operation, the amount of power lost in the distributing conductors at full load, even, being inconsiderable over the distances common in machine shops.

The saving of power to be effected by an electrical equipment, as compared



AN ELECTRICALLY-DRIVEN RADIAL DRILLING MACHINE AT THE BALDWIN LOCOMOTIVE WORKS

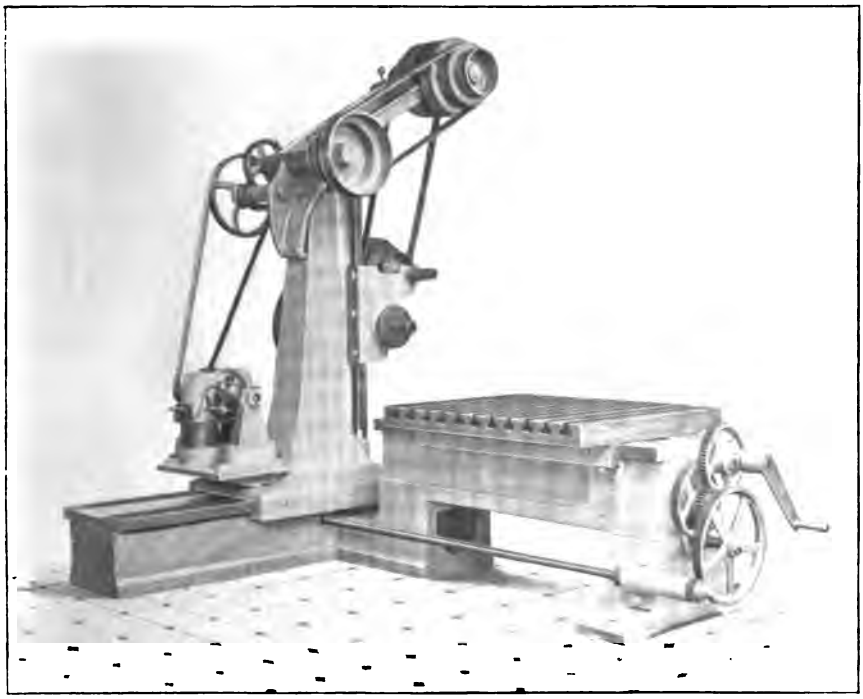
with a steam engine equipment driving shafting, is strikingly illustrated by a series of experiments made a few years ago in the shops of the Westinghouse Air Brake Company, at Wilmerding, Pa. These shops were originally equipped with what was, for the time, an excellent system, consisting of a central boiler plant furnishing steam through underground pipes to thirty steam engines, varying in capacity from 5 H. P. to 225 H. P. each, and located in the various buildings with a view to reducing shafting and belting to a minimum. The boiler plant contained sixteen boilers of about 2000 aggregate H. P. This equipment was replaced by a steam turbine plant, consisting of three turbines of 500 H. P., driving two-phase alternators, with electrical distribution to induction motors throughout the shops. Current is also used for lighting. The indicated horse-power of the engines required to drive the machinery amounted to 949.12, whereas the total electrical horse-power at the switchboard to replace this was about 600. In all, there are 57 motors with an aggregate nominal capacity of 1065 H. P. The percentage of coal saved varied during the tests from thirty per cent. to forty per cent.

These tests indicated the difference in the two methods of power distribu-

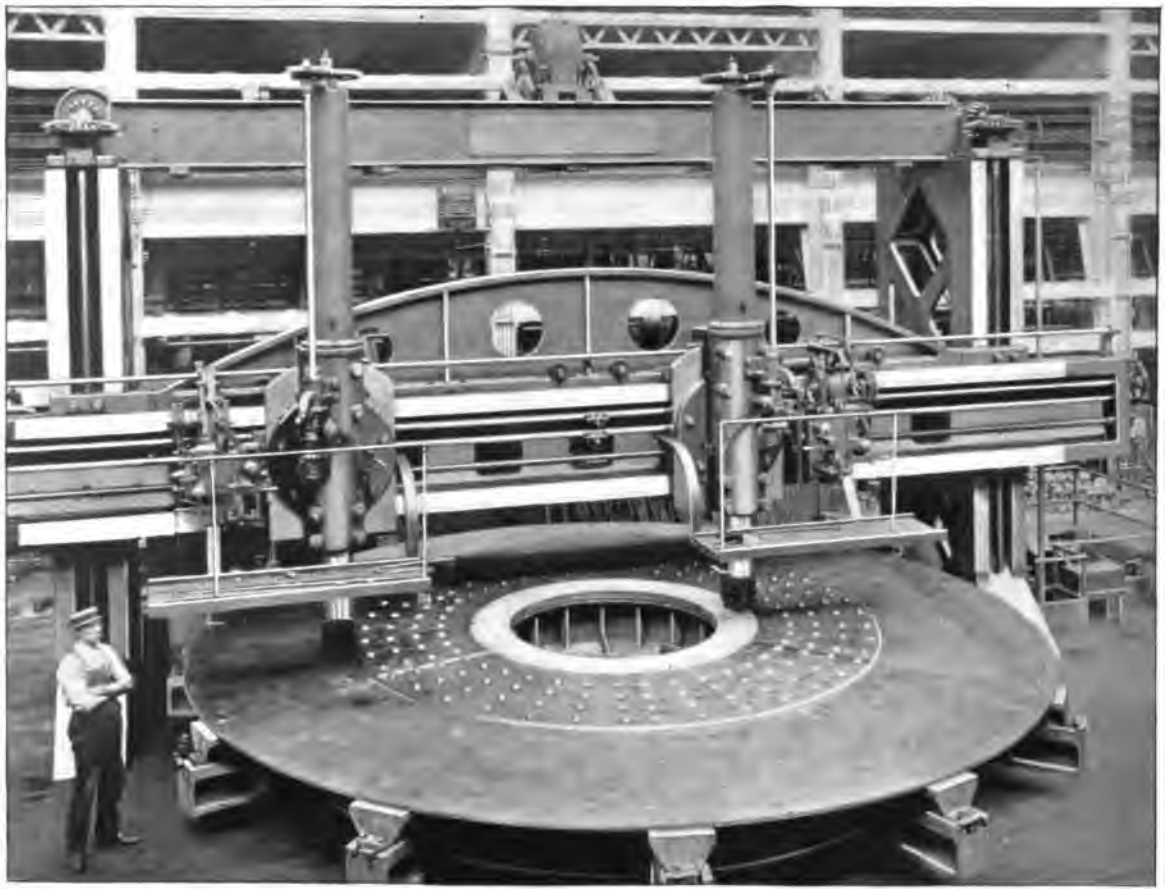
tion under every-day working conditions and showed that the turbines and motors saved 40,000 pounds of coal in twenty-four hours, including one day and one night run. This was due to the superiority of the entire electrical installation. A part of the saving came from the turbines, part from reduced lost work, and part in the prevention of steam pipe condensation.

A subject to which much attention has been directed, of late, is the matter of speed control of machine tools. It has been brought into prominence largely as a result of efforts to push the capacity of tools and shops to the maximum limit and in connection with the use of new special tool steels which permit much higher cutting speeds than had previously been possible. By careful attention to the sequence of operations and to instructing the men in securing the highest possible cutting speeds, the capacity of shops has even been doubled without increase in the equipment and little increase in the working force.

The use of the electric motor drive has been a potent factor in obtaining this result, not only, as pointed out before, by permitting the use of overhead cranes and the arrangement of machines with regard to the progress of the work, by its great flexibility and by its influence towards increased light and cleanliness, but also, to some extent, by the fact that it gives increased ease of speed control over driving by belts from shafting. In addition to the great facility of starting and stopping by means of switches located at any convenient place about a machine, the speed can be brought up to the limit that the particular work will stand. Take, for example, a lathe in which the increment of speed from step to step of the cones is quite large; then if a piece of work cannot be run quite as



AN ELECTRICALLY-DRIVEN HORIZONTAL BORING MACHINE MADE BY MESSRS. GREENWOOD & BATLEY, LTD., LEEDS, ENGLAND



A LARGE, ELECTRICALLY-DRIVEN BORING MILL. THE CROSS-HEAD IS RAISED AND LOWERED AND THE SADDLES ARE TRAVERSED BY INDEPENDENT WESTINGHOUSE MOTORS

fast as a given speed, the belt must be shifted to give the next lower speed, though that speed may be too low, thus requiring more time than is really necessary for the completion of the cut. On the other hand, if the tool were driven by an independent motor having a considerable range of speed, the maximum cutting speed at the tool could be obtained at all times. On large tools the cutting time is often seventy per cent. of the whole time, so that the saving becomes quite important as regards the output of both the tool and the operator.

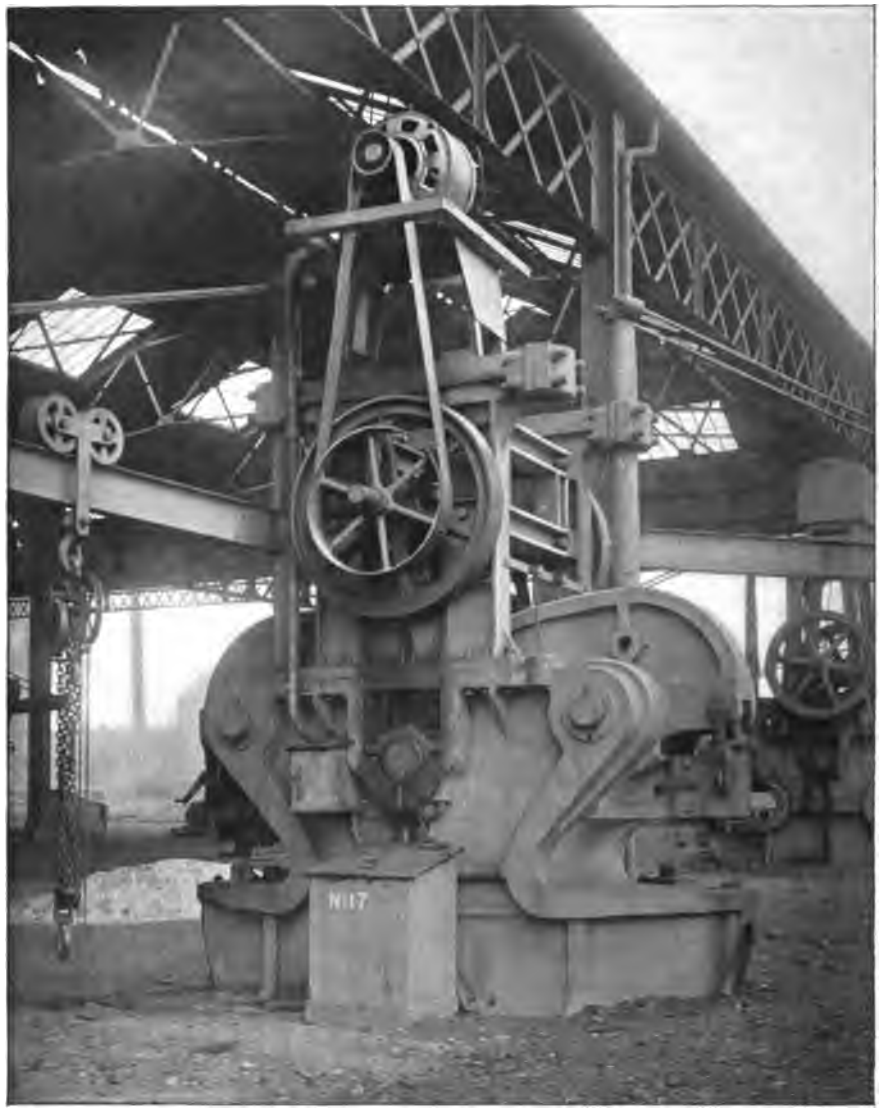
In addition to the advantages of reduction of shop expenses and the better utilisation of space incident to the electric drive, there are certain classes of work and tools for which it is almost alone adaptable. For heavy work it has been found that instead of bringing the work to the machine, the latter, when motor-driven, may with much greater advantage be carried to the work. Such tools are designed for all purposes, such as boring, planing and milling, and are sometimes very large. These tools are usually operated upon a floor consisting of bed-plates to which work may be fastened in the most convenient situation, the tools required being then brought to the work.

While a separate motor to each tool is necessary in order to realise the advantages of fine gradations in speed control or the convenience of portability referred to above, there remains a large class of tools in which the advantages of independent motors are overbalanced by the extra cost and multiplication of parts. Where large numbers of small lathes, turret screw machines, shapers, boring machines, drilling machines, and the like are grouped together, it is found advantageous to operate all from a short jack-shaft driven by an electric motor. These tools, as a rule, are used on work which is produced in large quantities and run at a certain fixed speed. By using a motor of 10 H. P. to 20 H. P. to drive a group, all the advantages of electric transmission in the shop are secured, while, at the same time, the motor driving the group will be of less capacity than the aggregate of the individual motors that would be required. It will also be more efficient and will require less attendance.

In the transition to electric driving in shops already equipped with belts and shafting, the group system is found most convenient, as machines that are already conveniently located, may be left where they are, and the short lengths of jack-shafting may be belted to electric motors of suitable capacity. However, for large machines which work only intermittently, or demand independent control, it will usually be found advisable to install individual motors.

AN ELECTRICALLY DRIVEN GRINDER MADE BY THE W. F. & JOHN BARNES CO., ROCKFORD, ILL., U. S. A.

There are concomitant advantages arising from the introduction of electric power in the machine shop which may be mentioned here. The electrically driven overhead crane is now the most indispensable part of a machine shop equipment where heavy work is handled. The convenience, quickness, and ease of control of a three-motor crane is so



A DOUBLE PUNCH, BUILT BY MESSRS. SMITH BROTHERS & CO., GLASGOW, SCOTLAND, DRIVEN BY A 27-H. P. ELECTRIC MOTOR. INSTALLED IN THE SHIPYARD OF MESSRS. R. STEPHENSON & CO., LTD., HEPBURN-ON-TYNE, BY MESSRS. WARREN, BEATTIE & CO., LTD., MIDDLESBORO, ENGLAND

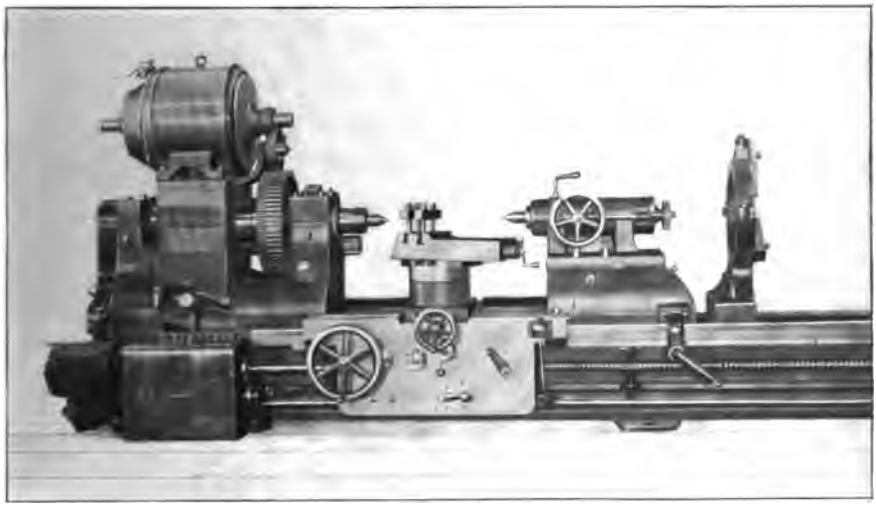
much greater than that of a crane driven by a flying rope or a square shaft, that the use of the latter is not to be thought of where electric power is available, and, indeed, many electric plants have been put in primarily for the operation of electric cranes. Electricity may be used for driving a great variety of small tools not usually classified as machine tools, and principally replacing hand labour, such as small drills, reamers, emery wheels, etc. Electric motors may also be used advantageously for operating blowers for ventilating and for forges; for operating pumps supplying elevators and

hydraulic presses; and for operating air compressors furnishing air to small air-driven tools, such as were mentioned in the first part of this article. Electric lighting on account of its safety, cleanliness, convenience and effectiveness, is found so valuable that machine-shop owners are usually justified in putting down an electric plant for this purpose alone.

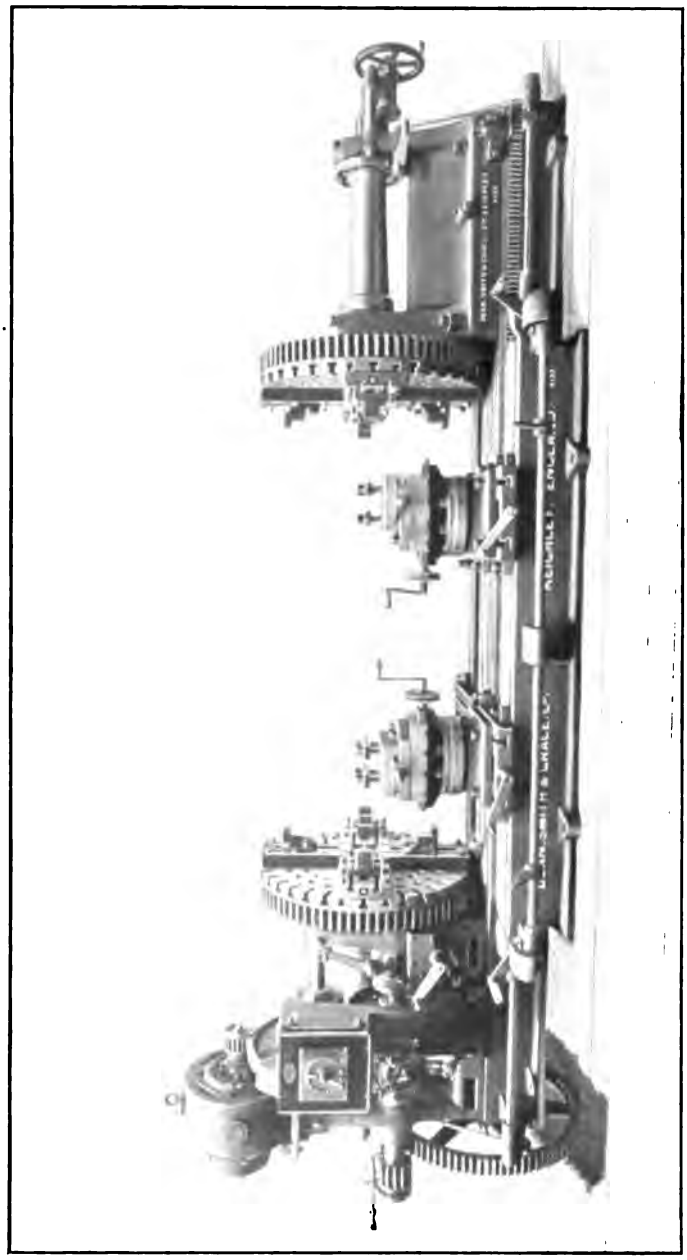
The several systems of electric distribution are divided into direct-current systems and alternating-current systems. Direct-current motors may be divided into constant-current motors and constant-potential motors; and the latter again into series motors, shunt motors, and compound motors. Constant-current motors have never been used except to a small extent, and then in connection with arc lighting circuits.

In the series motor the current passes through the armature and then directly through the field winding. Inasmuch as the torque, or turning moment, of a motor is roughly equal to the armature current multiplied by the field strength, the torque of this motor usually increases nearly as the square of the current. It is, then, a very suitable motor for starting and accelerating heavy loads, as in traction and crane service. On the other hand it is entirely unsuited for any work requiring close speed regulation, as will be evident from the following considerations.

When a motor is running, the current through its armature is limited by the resistance of the conductors, which remains constant, and by the counter electromotive force developed by the armature winding revolving in the magnetic field, which is proportional to the product of the field strength and armature speed. Now, suppose that a series motor with a given load is running steadily at a certain speed and torque. If the load be decreased, less torque will be required, and hence the speed will tend to increase. The increased speed will raise the counter-electromotive force which, in turn, will cut down the current. With less current the field will be weaker and the motor must run faster in order to generate the same counter-electromotive force as before. That is, for every given load, torque, and current, the motor has a certain speed. If such a motor were, for instance, driving a lathe doing a piece of work in which the tool was cutting metal only part of the time, the



A MOTOR-DRIVEN LATHE MADE BY THE LODGE & SHIPLEY MACHINE TOOL CO., CINCINNATI, OHIO, U. S. A.

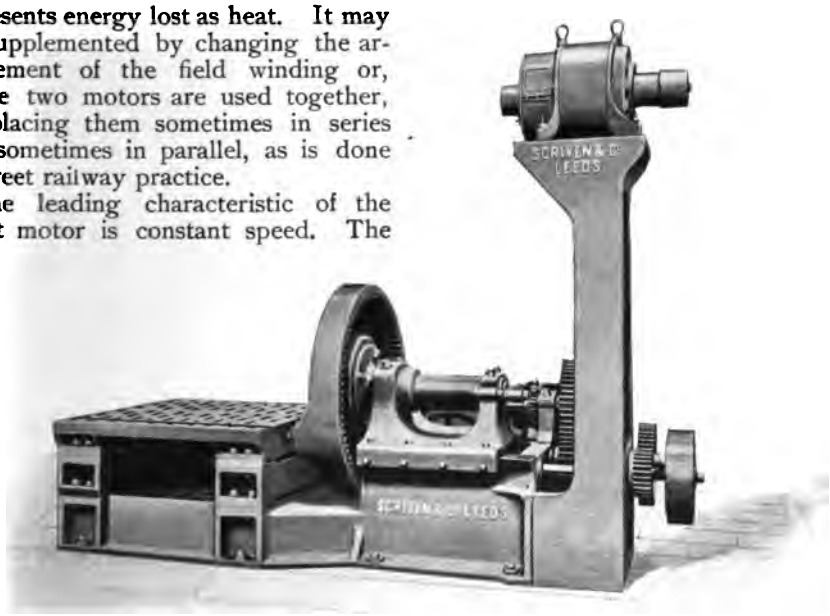


AN ELECTRICALLY-DRIVEN DOUBLE RAILWAY WHEEL LATHE BUILT BY MESSRS. DEAN, SMITH & GRACE, LTD., KEIGHLEY, ENGLAND. THIS LATHE WAS BUILT FOR TURNING WHEELS UP TO 4 FEET IN DIAMETER, AND IS DRIVEN BY A 5 BRAKE-HORSE-POWER MOTOR

motor would accelerate rapidly during the time the tool was not cutting and the work might strike the tool again with such speed and force as perhaps to wreck the machine. On the other hand, where the motor-controlling device is constantly under the hand of the operator, the series motor is unexcelled.

The series motor is usually controlled by inserting in the circuit resistance which serves to cut down the applied electromotive force and so reduce the speed. This method of control is wasteful, since the proportion of the electromotive force consumed in the resistance represents energy lost as heat. It may be supplemented by changing the arrangement of the field winding or, where two motors are used together, by placing them sometimes in series and sometimes in parallel, as is done in street railway practice.

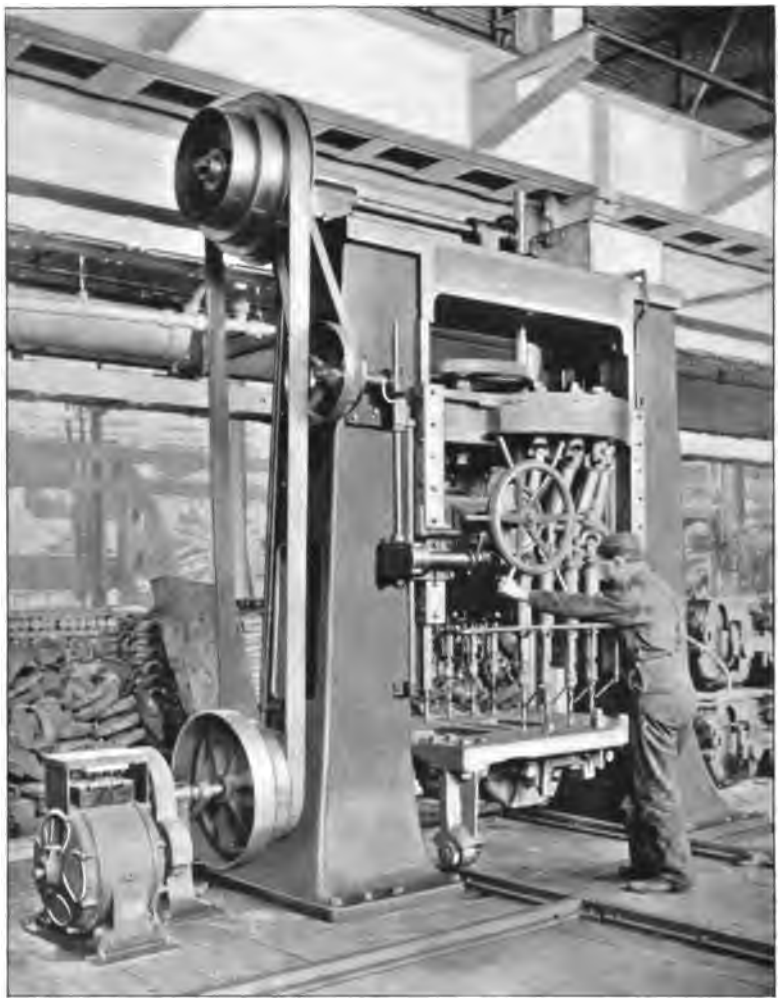
The leading characteristic of the shunt motor is constant speed. The



A COLUMN AND GIRDER END FACING MACHINE BUILT BY MESSRS. SCRIVEN & CO., LEEDS, AND EQUIPPED WITH AN ELECTRIC MOTOR BY MESSRS. CROMPTON & CO., LTD., LONDON

field winding is at all times connected directly across the supply mains, and hence the field is of constant strength. As before pointed out, the electromotive force lost in the resistance plus the counter-electromotive force developed must equal the applied electromotive force, and the counter-electromotive force is proportional to the product of the speed and field strength. Since the armature resistance of a properly designed motor is very small, it consumes only a few volts, even when a large current is flowing. Therefore, the counter-electromotive force must be at all times nearly equal to the applied electromotive force and the speed must be nearly constant. The torque, since the field strength is constant, is only proportional to the armature current, making this type of motor not as suitable as the series motor for starting heavy loads. Speed regulation may be obtained by varying the electromotive force applied to the armature or by varying the strength of the field by means of resistance inserted in the field circuit. By the first method a speed variation from zero to full speed may be obtained and by the second, with machines suitably designed, we may obtain a speed ratio of 3 to 1.

In order to vary the electromotive force applied to the armature, two methods are available. Resistance may be introduced in the armature circuit

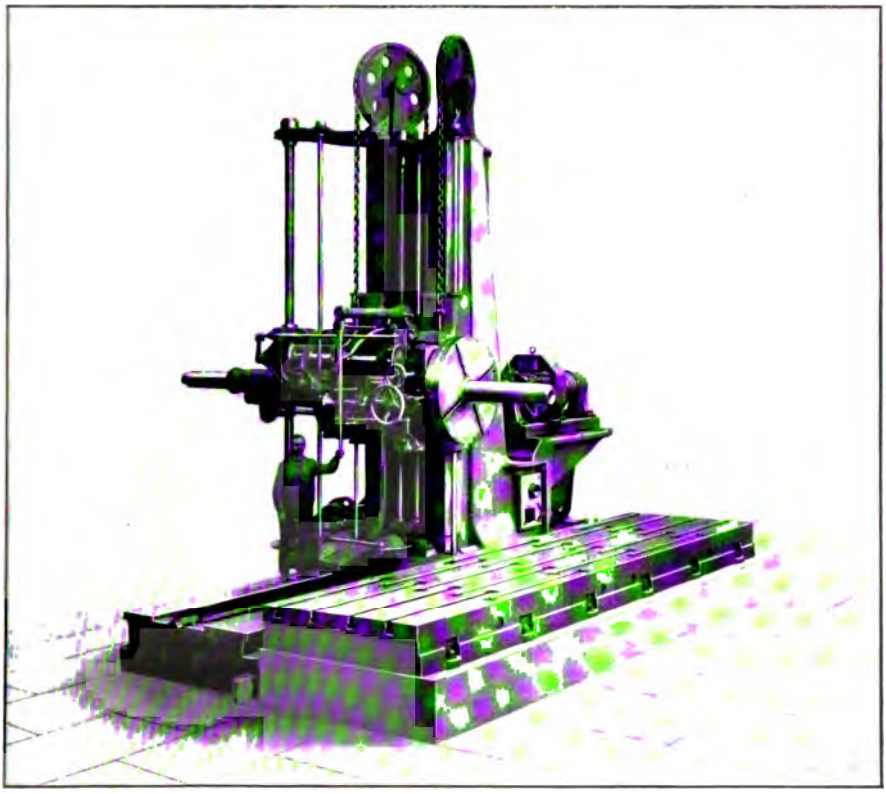


A WESTINGHOUSE INDUCTION MOTOR DRIVING AN 8-SPINDLE DRILLING MACHINE BUILT BY THE PRATT & WHITNEY CO., HARTFORD, CONN., U. S. A.

to cut down the electromotive force acting upon the armature. This method, however, is unsatisfactory for some purposes, for two reasons:—First, a large amount of energy is wasted as heat in the resistance; for instance, if the speed is cut in half, as much energy is wasted as is used. Secondly, the motor loses its desirable quality of close speed regulation. Suppose that the motor is running with resistance in circuit and the load is decreased; the current then also decreases, thereby lessening the electromotive force consumed in the resistance, since that equals the product of the current and the resistance. A greater electromotive force is, therefore, left to act upon the armature and the speed rises in consequence.

Another way in which the electromotive force applied to the armature of a shunt motor may be varied is by making use of a multiple-wire system, or a number of circuits working at different voltages. Suppose that, commencing with the negative wire, the rise in voltage to the second wire is 60 volts, that the next interval is 80 volts

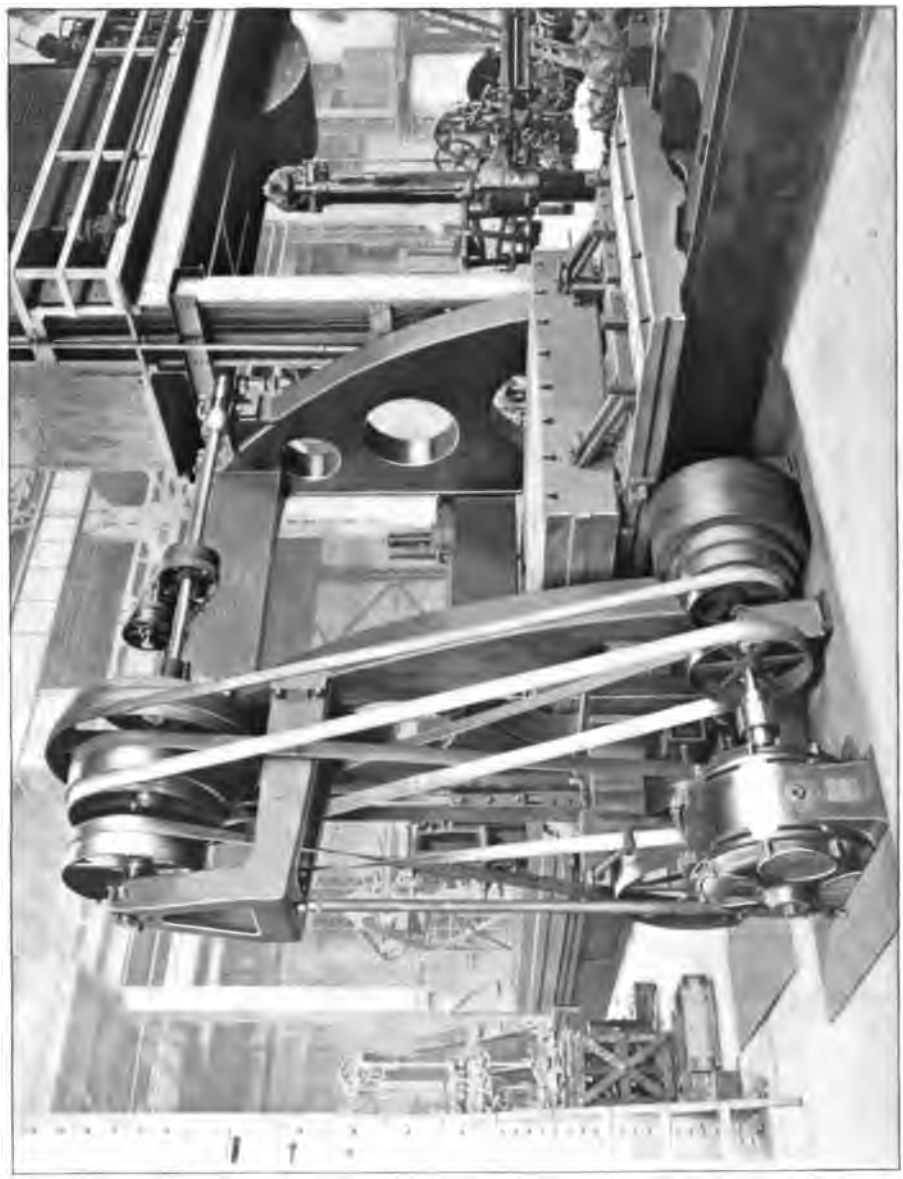
and that the third interval is 110 volts. We may then get any of these three voltages, and in addition, by connecting from the first to the third, we may get 140 volts, from the third to the fourth 190 volts, and from first to fourth 250 volts, or, in all, six voltages. If the field of the shunt motor is constantly excited by 250 volts, the several voltages applied to the armature will give as many different speeds and the gaps between may be filled in by slightly varying the field excitation.



AN ELECTRICALLY-DRIVEN HORIZONTAL BORING MACHINE BUILT BY ERNST SCHIESS, DUSSELDORF, GERMANY

This method of speed control seems in a way ideal, but it has against it, nevertheless, some rather serious objections, especially in the way of first cost, complication, and upkeep. In order to obtain the multiplicity of voltage given above, we would need three separate generators or else a generator supplying the outside voltage and a balancing set to furnish the intermediate voltages. The balancing set would be of the same or greater aggregate capacity, and cost more than the generator, since there is a possibility that every machine in the shop may at the same time be thrown upon one of the voltages. The wiring system is complex, since four wires must be run to every machine. The controller of the motor, which is often called upon to break the full armature current, is also complicated and liable to get out of order.

The motor itself is much larger than it would need to be if suitable mechanical speed reduction gears were used for the low speeds. The capacity of a motor is proportional to the product of its speed and the amount of current it can carry without overheating. There-



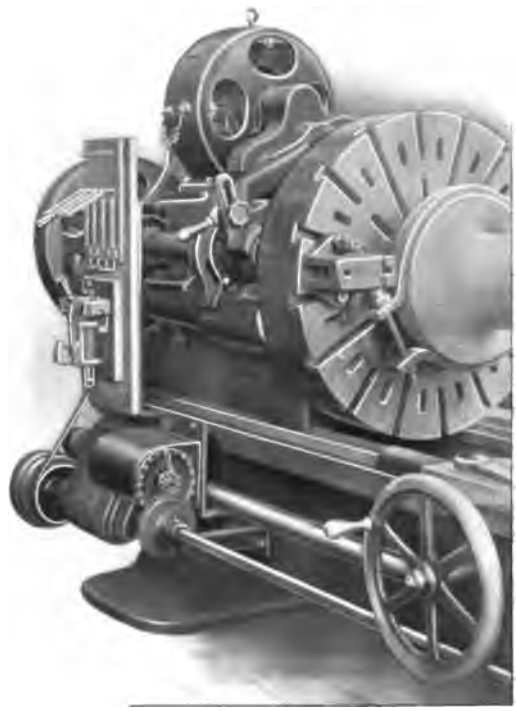
A 42-INCH PLANER DRIVEN BY A 30 H. P. INDUCTION MOTOR IN THE SHOPS OF THE WESTINGHOUSE ELECTRIC & MFG. CO., PITTSBURGH

fore, if a motor is run at less than its full speed it has proportionately less capacity. On the other hand, many machine tools require the same amount of power whether running at fast or slow speed.

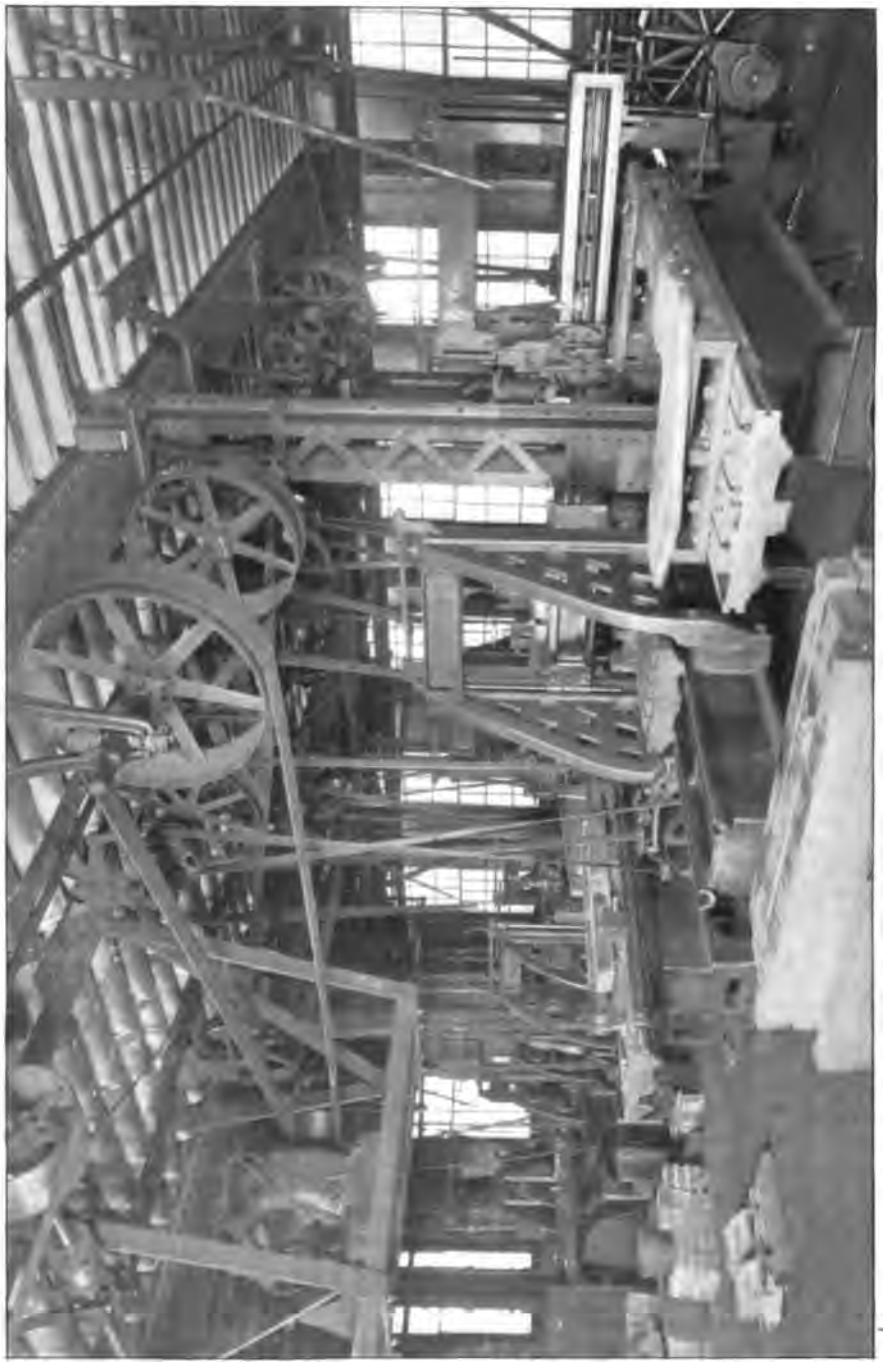
Taking a lathe, for instance, the slow speed is used for cutting upon large diameters, and, disregarding finishing cuts, dull tools, etc., the cutting speed of the tool, depth of cut and work performed are in both cases nearly the same; therefore, the power needed will be practically constant throughout the whole range of speeds. If the motor is geared directly to the tool and the speed control is affected by varying the electromotive force applied to the armature, the motor will have to be large enough to furnish the maximum power at its slowest speed, and, hence, many times larger than if it ran constantly at full speed and a mechanical reduction gear were used for lower speeds.

Of such mechanical speed changing gears there are many on the market, both efficient and easy of manipulation. Perhaps one of the best is the old and well-tried device of stepped cones and belts. If the motor is fastened upon the frame of the machine to be driven, of course a short belt drive must be used, but the motor can be so hung that the belt can be tightened or loosened by merely throwing a lever, thus making it easy to change the belt from one speed to another or to tighten it to prevent slipping. Other devices are changeable toothed gears, cone pulleys and the Reeves pulley, which has lately come into extended use.

The objections above noted against multiple voltage systems, namely high cost and complication of the generating and distributing plant, are largely avoided by a three-wire system which has recently been introduced. A special generator is employed, somewhat resembling a rotary converter,—that is, in addition to the brushes and commutator furnishing direct current, leads are brought out from the armature winding to two or more slip-rings placed upon the armature shaft. From these slip-rings alternating currents may be taken. If the alternating current is passed through a simple device consisting of a coil of wire wound around an iron core and known as an auto-transformer, and if a lead is tapped off from the middle of the coil, this lead will always have a potential midway between that of the terminals of the direct-current side of the machine and we may thus have at the motor two voltages, one equal to twice the other. As

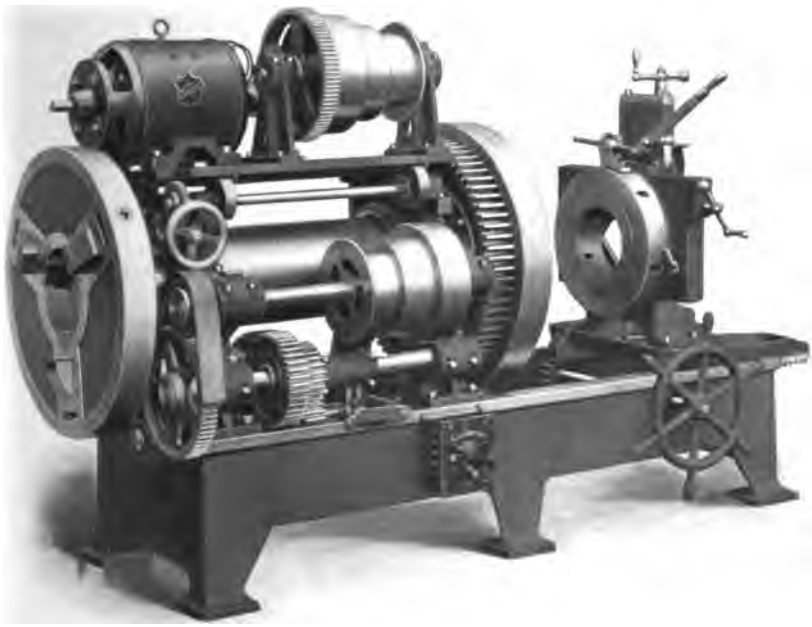


A LATHE OPERATED BY A CROCKER-WHEELER MOTOR WITH A MULTIPLE-VOLTAGE SUPPLY OF POWER. THE BOARD AT THE LEFT SHOWS THE SWITCH, FUSES AND CIRCUIT BREAKER. THE CONTROLLER IS MOUNTED HORIZONTALLY AT THE BASE OF THE FRAME, OPERATED THROUGH GEARING FROM A HANDLE ON THE TOOL CARRIAGE CONNECTED WITH THE SPLINED SHAFT SHOWN



AN EXAMPLE OF ELECTRIC GROUP DRIVING AT THE BALDWIN LOCOMOTIVE WORKS, PHILADELPHIA. THE GANG OF PLANERS IS OPERATED BY THE OVERHEAD ELECTRIC MOTOR SHOWN AT THE LEFT, MADE BY THE CROCKER-WHEELER COMPANY, AMPERE, N. J., U. S. A.

pointed out before, the speed of a suitably designed motor may be varied, through a ratio of 2 or 3 by regulating the field current and, so, if such a motor is used in connection with the three wire system, we may obtain all the speeds possible with the four-wire system above described, and at much less expense and complication. In addition, if desired, the three-wire generator may be used for furnishing alternating currents for the operation

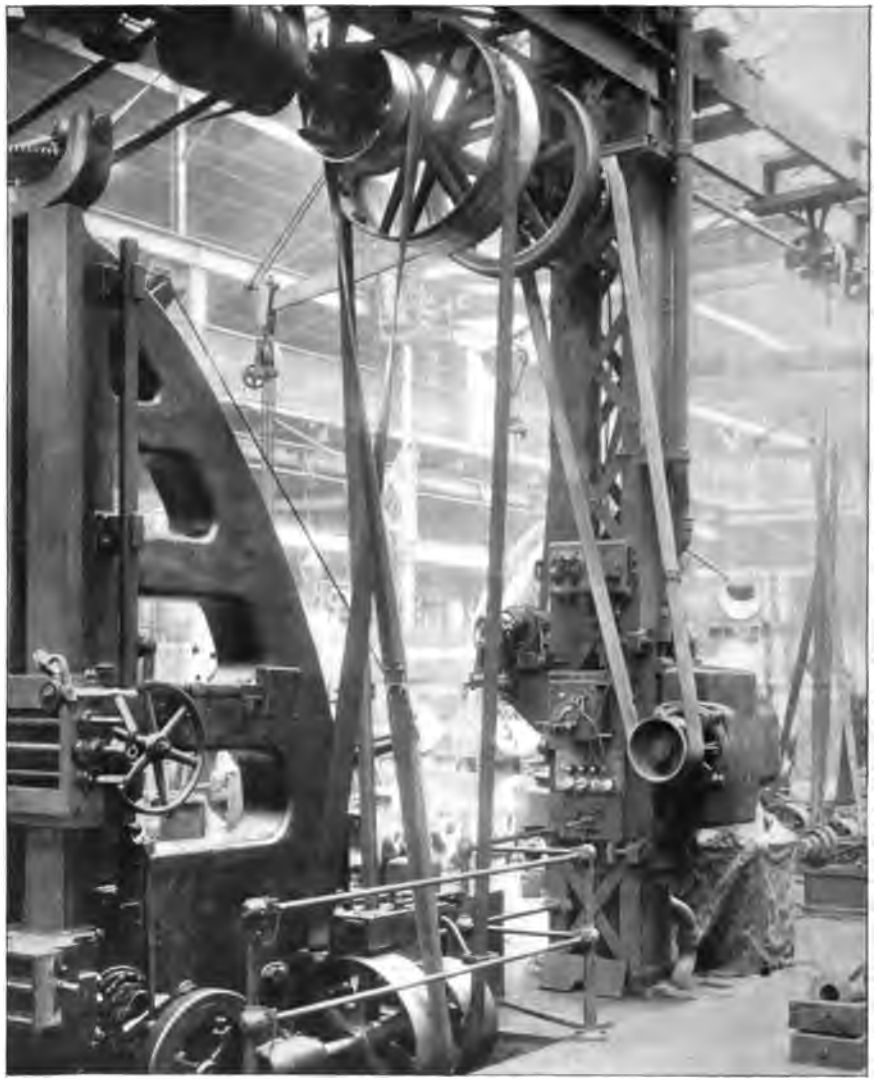


A MOTOR OF THE BULLOCK ELECTRIC MFG. CO., CINCINNATI, OHIO, DRIVING A PIPE THREADING MACHINE MADE BY THE BIGNALL & KEELER MFG. CO., EDWARDSVILLE, ILL., U. S. A.

of induction motors or for high-voltage transmission. In size and weight it is practically equivalent to an ordinary direct-current generator of the same capacity.

By placing the armatures of two shunt motors in series across constant-potential mains, it is possible to divide the voltage, and, therefore, reduce the speed. The same results may be obtained from two windings with separate commutators upon the armature of a single motor. The voltage consumed by either winding at a given speed is proportional to the number of turns comprised by that winding, and, if the two windings have unequal numbers of turns, widely different speeds may be obtained by employing the windings separately and in combination. Suppose that one of the windings has more, but not twice as many, turns as the other; then the lowest speed will be obtained when both are switched in parallel; the next higher speed when the larger winding is used alone; the third, when the smaller is used alone; and the highest speed, when the windings are so connected that the lesser opposes the greater. It will be noted that this method involves the use of two commutators and complex switching arrangements.

However, it has been proposed to employ the above method in combination with another of almost equal complexity. If we have a multipolar motor, that is, one having more than one pair of field poles, we may vary, or even reverse, the excitation of some of the

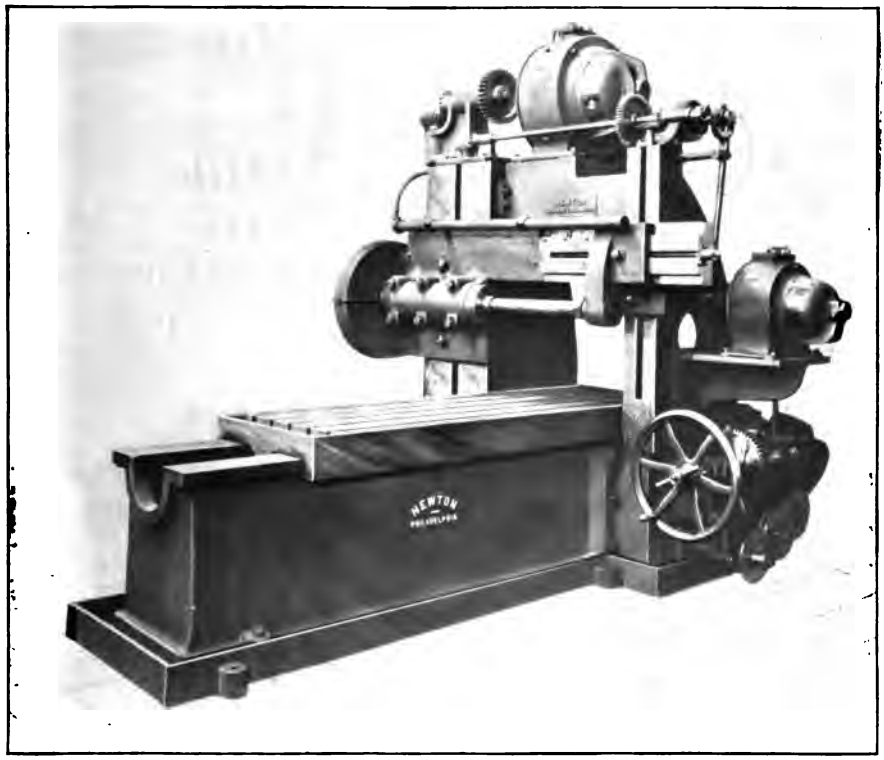


AN ELECTRIC MOTOR, FIXED AGAINST A COLUMN, DRIVING A BORING MILL THROUGH BELTS AND SHAFTING. THE MOTOR DRIVES THE ONE MACHINE ONLY. INSTALLED BY MESSRS. MATHER & PLATT, LTD., MANCHESTER, ENGLAND

pairs, and in that way greatly modify the speed, and incidentally produce a considerable unbalanced pull upon the armature shaft. When the two methods are combined, a great range of speed control is secured, but at a greater cost in the way of complexity and multiplicity of commutators, switches, controllers, resistances, etc , all especially liable to get out of order and requiring constant care and attention. Either of the methods, or both in combination, imply a much larger motor for a given output than would otherwise be required, since it is evident that when part of the motor is inactive, or working in opposition to the remainder, the capacity of the motor is greatly reduced. In both systems when the whole motor is working as a unit, it is operating at a

slow speed and consequently low capacity. The greatest objection to both systems, however, is in cost of up-keep. If the commutator and controller of an ordinary direct-current motor are sources of objectionable care and expense, matters are not improved by doubling or tripling the number and complexity of these devices and by introducing conditions unfavourable to long life of the commutator and bearings. Before leaving this subject, we may mention still another system of motor control that has been proposed, and, to some extent, used for certain special purposes. By varying the field strength of a generator, we can vary its voltage, and, therefore, the speed of the motor supplied by it, provided, of course, that the field of the latter is constantly excited from an independent constant potential circuit. It is possible in this manner to obtain any speed from zero to full, and, by reversing the field, to reverse the motor; but a separate generator is required for each motor.

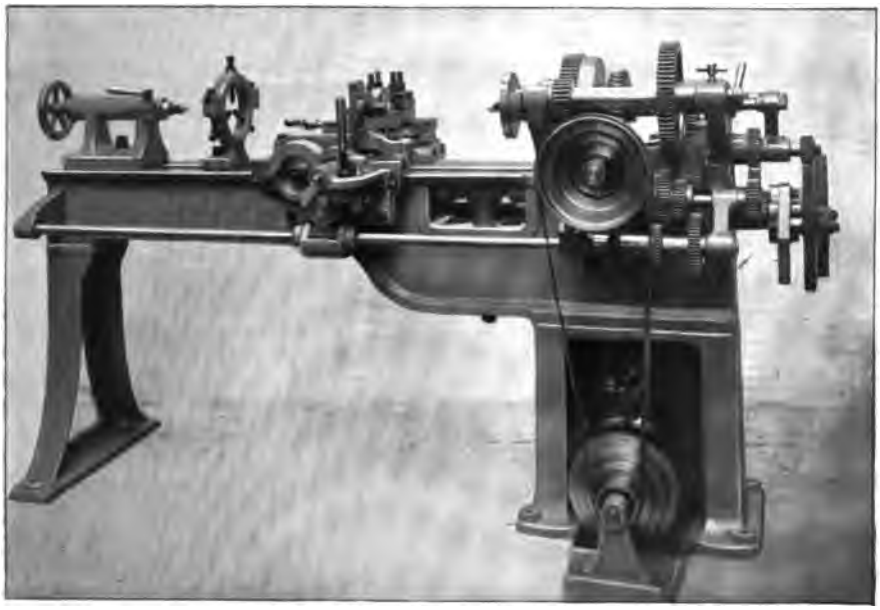
However, we may install a generator supplying current at constant voltage to motor generator sets, one of the latter for each working motor operated. By manipulating the generator field of the motor-generator set, we may obtain all the results above described. Again, the motor-generator set may take the form of a "booster," with the generator armature directly in series



A HORIZONTAL MILLING MACHINE FOR PANELLING RODS OR OTHER WORK OF SIMILAR NATURE, BUILT BY THE NEWTON MACHINE TOOL WORKS, PHILADELPHIA, PA., U. S. A. THE ENTIRE MACHINE IS SET IN A PAN AND THE MOTOR ON TOP IS THE MAIN DRIVING MOTOR. THE SMALL MOTOR AT THE SIDE IS BELTED TO THE LIFTING SHAFT FOR QUICKLY ADJUSTING THE HEAD AND ALSO TO THE QUICK-RETURN PULLEY, MAKING EITHER OF THESE MOTIONS INDEPENDENT OF THE DRIVE OF THE SPINDLE

with that of the working motor. If the booster voltage operates against the line voltage we may reduce the electromotive force applied to the working motor, and hence its speed, to zero, or, by reversing the booster field, we may add its voltage to that of the line and so increase the speed of the working motor. The complication, first cost, and operating cost of this method are sufficiently evident without further description. All the disadvantages in regard to motor capacity urged against the multi-voltage systems apply here as well. It may also be noted that the capacity of the motor-generating set must be equal to that of the working motor. This system has been brought forward by Mr. H. Ward-Leonard and is known by his name. It has been

A TEN-SPINDLE DRILLING MACHINE MADE BY THE PRATT & WHITNEY CO., HARTFORD, CONN., U. S. A. DRIVEN BY AN INDUCTION MOTOR OF THE WESTINGHOUSE ELECTRIC & MFG. CO., PITTSBURGH, PA.



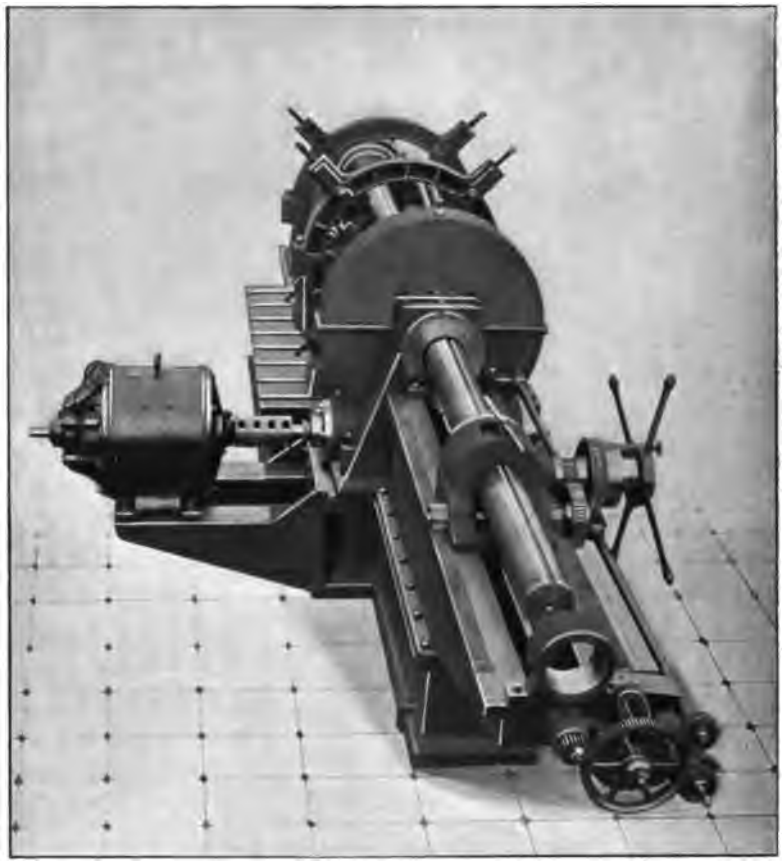
A LATHE BUILT BY MESSRS. JAMES ARCHDALE & CO., BIRMINGHAM, ENGLAND, DRIVEN BY A LUNDELL ELECTRIC MOTOR

found well adapted for turning the turrets of battleships, where very accurate control is needed

The compound motor is a compromise between the series motor and the shunt motor, since its field is excited by both series and shunt windings. It starts with a relatively high torque, like the series motor, and, like the shunt motor, it will not race. It is especially useful where a good torque is desired and where close speed regulation is not important, as in the operation of pumps and blowers. The same methods are used for controllling compound motors as are employed in the case of shunt and series motors.

Alternating current systems of power distribution, although the last to come into commercial use, possess pre-eminent advantages and are finding wide application for power distribution in machine shops and factories. For power work, alternating currents are always distributed at constant potential. An alternating current, as the name indicates, rapidly alternates in direction of flow, in commercial systems at the rate of from 25 to 130 complete double alternations or cycles per second. The various systems in use are divided into single-phase and poly-phase, the latter comprising two-phase, three-phase, etc. The two-phase system consists in reality of two single-phase circuits, in one of which the current reverses just a quarter of a period after the other, or while the other is at its maximum value in one direction. Two-phase currents require three or four wires for their distribution. In the three-phase circuit, three wires are employed, in which the currents reverse one after the other in rotation. It so happens that the value of the current in one wire is always equal to and opposite in direction to those in the other two wires, so that if the three wires are joined at their extremities no return circuits are necessary.

Alternating current motors are sharply divided into two distinct classes, synchronous motors and asynchronous, or induction, motors. The synchronous motor is the exact converse of the alternating current generator. It consists of a field constantly excited by a direct current and an armature into which



A HORIZONTAL CYLINDER-BORING MACHINE MADE BY THE MEADVILLE VISE CO., MEADVILLE, PA., U. S. A., DRIVEN BY A BULLOCK ELECTRIC MOTOR

alternating currents are fed. Now, if we consider one of the conductors of the armature as lying under one of the poles of the field and if a current is passed through this conductor, the latter will be urged in one direction. If the conductor remains under the same magnet pole and the current be reversed, it will be urged in the opposite direction, the effect of the two impulses being to nullify each other.

However, if the conductor, in response to the first impulse, has moved so that at the time of the reversal of current it lies under the next succeeding pole piece of opposite polarity, it will receive a second impulse in the same direction with its first motion. It will thus be seen that the synchronous motor must keep time or synchronise with the alternations of the circuit from which it is supplied, and that its speed is determined absolutely by the frequency of alternations in that circuit. It will also be seen that it is, in general, not self-starting, and that its field must be energised from some independent source of direct-current. It further requires an attendant if it is not to disturb greatly the circuit from which it is supplied. These considerations show its inadaptability for the requirements of a shop, except, possibly, where the apparatus driven requires a large amount of power and runs continuously all day at a fixed speed and load.

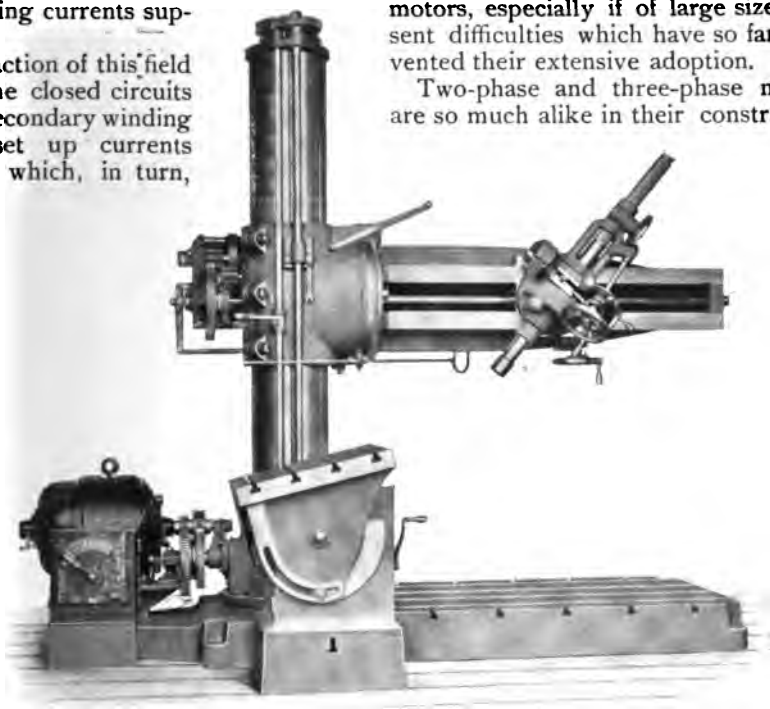
The induction, or asynchronous, motor consists of a primary winding

into which alternating currents are fed, and a secondary in which alternating currents are set up by induction, but which has no electrical connection with outside circuits, and, therefore, needs neither brushes, slip-rings, nor commutator. The action of the poly-phase currents in the primary winding is to set up a magnetic field which revolves as the currents reverse in rotation. The speed of this rotating field is, therefore, synchronous with the alternating currents supplied.

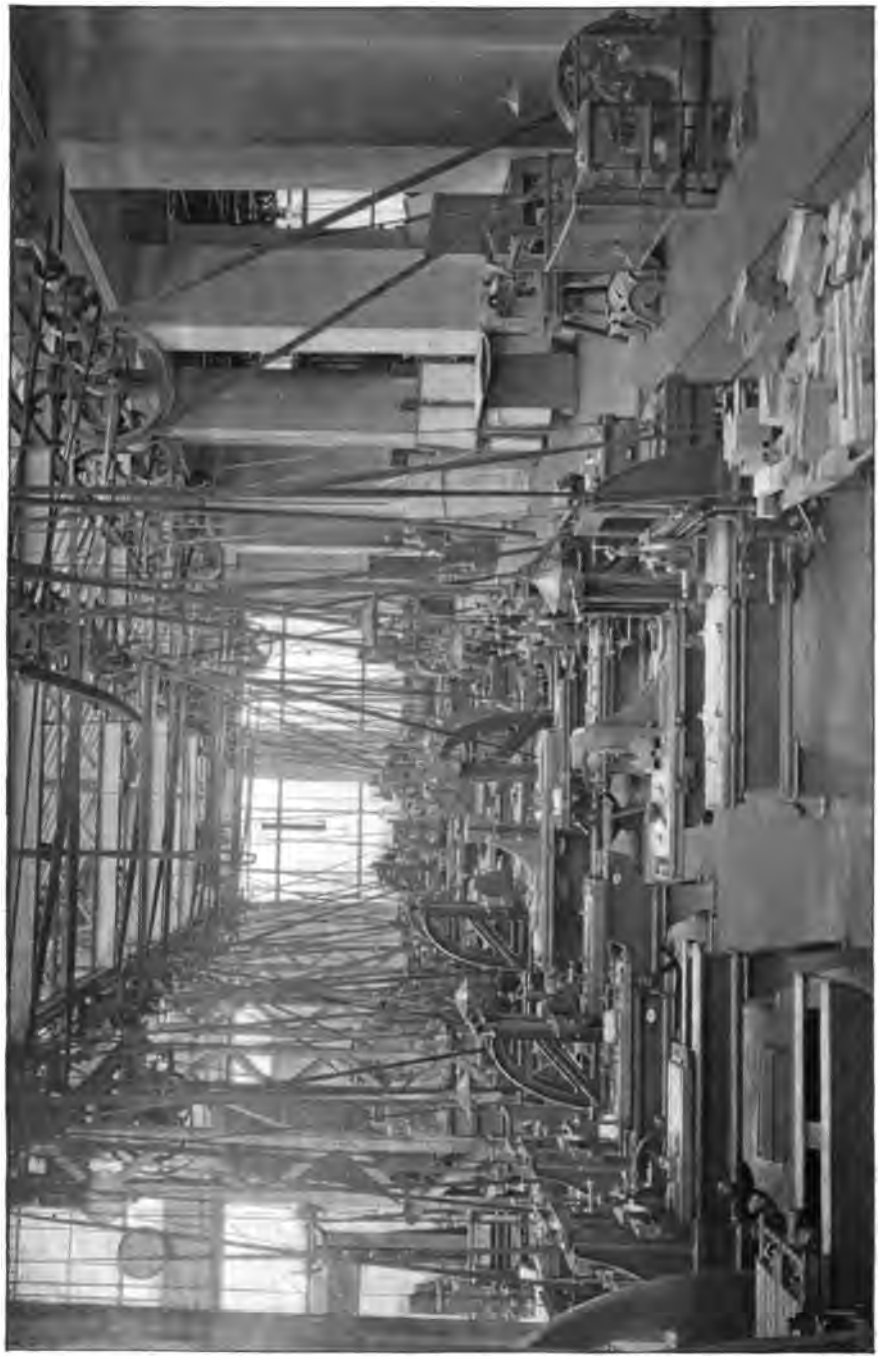
The action of this field upon the closed circuits of the secondary winding is to set up currents therein, which, in turn, react upon the field in such a manner as to cause the secondary conductors to be urged forward with the revolving field. They will tend to increase in speed until they are moving at the same speed as the rotating field; that is, the induction motor tends to run in synchronism, but never quite does so, in the same manner that the shunt motor tends to reach a constant speed at which the counter electromotive force is exactly equal to the applied electromotive force.

It is evident that induction motors may be used with either two or three-phase currents. They may also be used with single-phase currents when once started, and they may even be made self-starting through devices by which a current can be obtained from the main supply differing from the latter in phase. However, the construction and operation of single-phase motors, especially if of large size, present difficulties which have so far prevented their extensive adoption.

Two-phase and three-phase motors are so much alike in their construction and characteristics that the choice of one or the other system must be determined by considerations other than those relating to the motors. The wiring of three-phase circuits is the simpler and requires the smaller amount of copper, while with the two-phase system, lamps or other loads can be thrown upon one of the phases without unbalancing the circuit, which cannot be done with the three-phase system. The choice



A UNIVERSAL RADIAL DRILL WITH ELECTRIC DRIVE, MADE BY THE DRESES MACHINE TOOL CO., CINCINNATI, OHIO, U. S. A.



ELECTRIC MOTOR GROUP DRIVING IN THE SHOPS OF MESSRS. LUDWIG LOEWE & CO., LTD., BERLIN

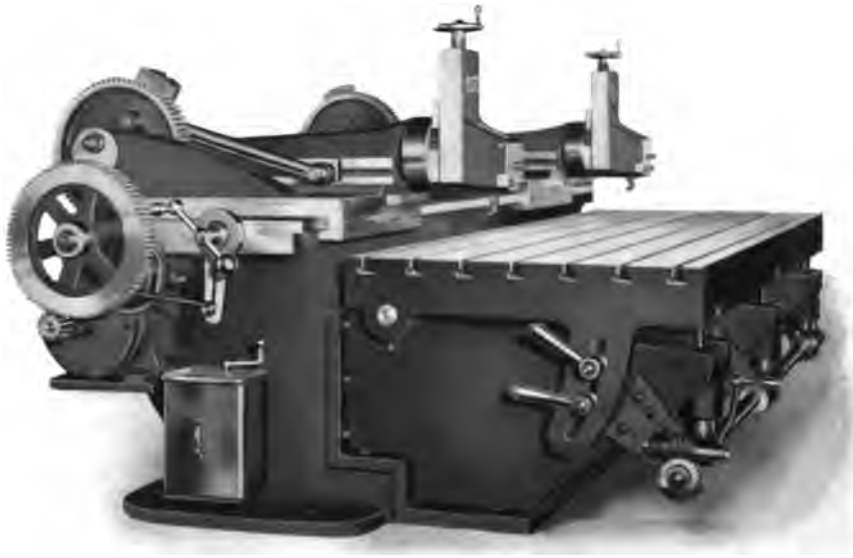
of one or the other systems will often be determined by the amount and character of the lighting to be done from the power mains.

The characteristics of the induction motor are similar to those of the shunt motor in that it tends to run at a certain fixed speed, and that when running below this speed it wastes power in proportion as the speed falls off. For driving those classes of machine tools for which adjustable speed is required, it is used in connection with speed-changing devices, such as were described when considering the shunt motor. However, it differs from the shunt motor in that the electrical controlling devices are very simple, consisting sometimes merely of a switch, and, at most, comprising a double-throw switch and an auto-transformer, the latter furnishing the large currents required for starting without drawing excessively upon the line.

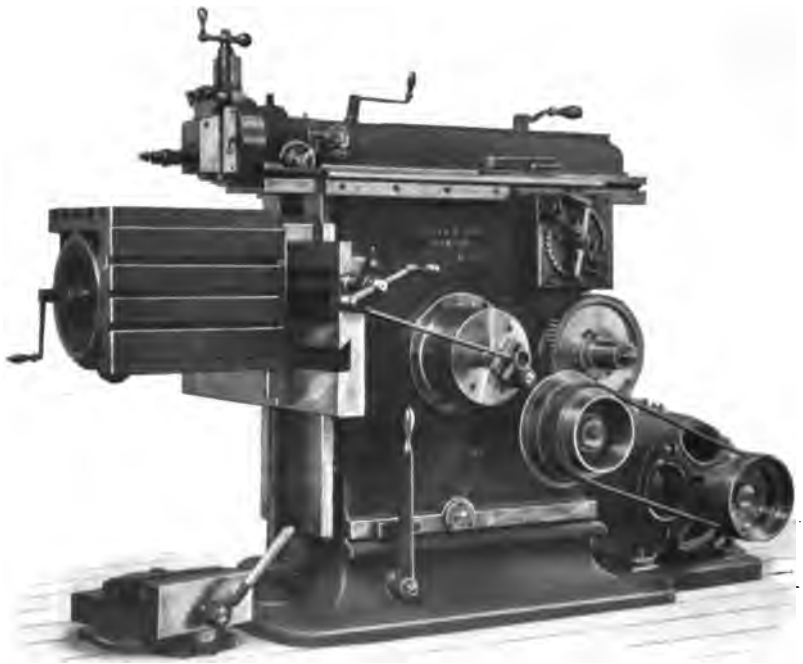
The rotating part of an induction motor, in the most usual type, consists of copper bars imbedded in steel laminations and fastened at their ends to rings, forming a " squirrel cage " winding. There are no moving contacts either for the secondary or primary, the latter being stationary and receiving current directly from the line. These motors are entirely unaffected by dust, have no brushes or commutators to be looked after and kept in order, and may be so much overloaded as to be brought to a full stop for a short time without injury, —a thing impossible with any type of direct-current motor. Further, they will start from rest with the starting-up of the generators and the entire shop may be shut down or started from the power house. They start with a torque equal to two or three times the full load running torque and will stand heavy overloads of short duration. The squirrel cage type of motor may be so modified in design that it will start with a very high torque and when so designed, it has comparatively poor speed regulation, but is especially suited to the requirements of crane service. These characteristics, with simplicity of construction, great durability, and constant speed, make this type of induction motor ideal for all purposes of machine driving. Its merits have brought about its adoption in many large shops, and often under the most severe conditions of service.

A SLOW-SPEED CROCKER-WHEELER MOTOR DIRECT CONNECTED TO THE SHAFT OF A BAND SAW, MADE BY THE NILES TOOL WORKS CO., HAMILTON, OHIO, U. S. A.

If the induction motor be provided with a variable resistance in the secondary circuit, its speed may be varied through wide limits in much the same way that the speed of the shunt motor

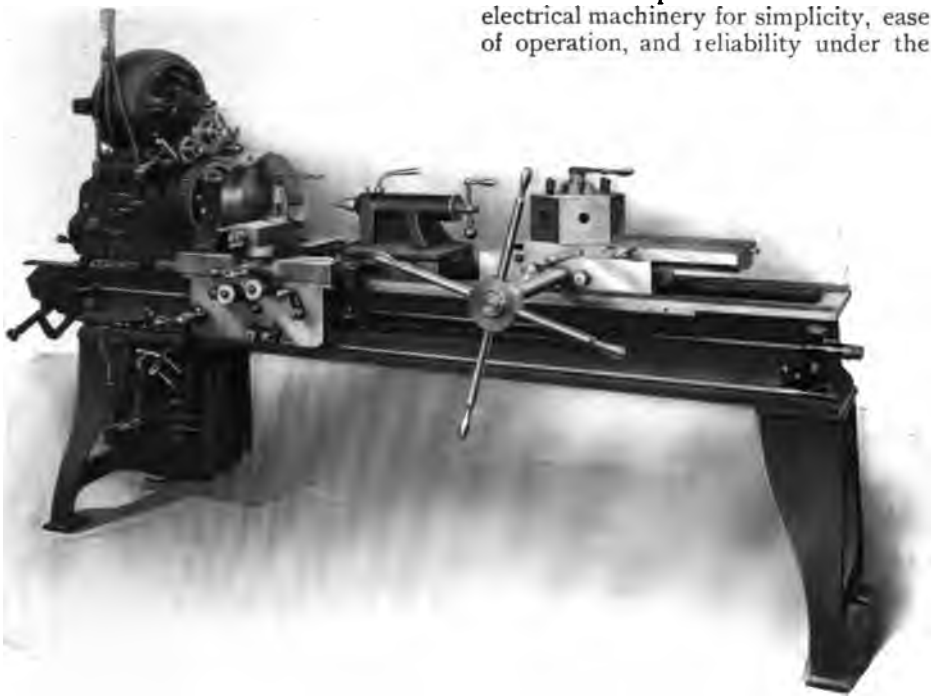


A DOUBLE-HEAD, DRAW-STROKE SHAPER, MADE BY THE FITCHBURG MACHINE WORKS, OF FITCHBURG, MASS., U. S. A. DRIVEN BY A BULLOCK ELECTRIC MOTOR.



AN ELECTRICALLY-DRIVEN SHAPING MACHINE MADE BY THE POTTER & JOHNSTON MACHINE CO., PAWTUCKET, R. I., U. S. A.

can be varied by inserting resistance in the armature circuit. Motors of this class have a very powerful starting torque, and good speed regulation when all the resistance is cut out, and are suitable for use on hoists, elevators, and similar service. They differ from the squirrel-cage type in having the resistance in the secondary meets all requirements of elevator, or other similar service, while the induction motor with squirrel-cage secondary is most suitable for machine tools requiring constant speed, or for crane service, when suitably modified in design. Both require no experience for their operation and are unparalleled in the field of electrical machinery for simplicity, ease of operation, and reliability under the most unfavourable conditions of care and surroundings.



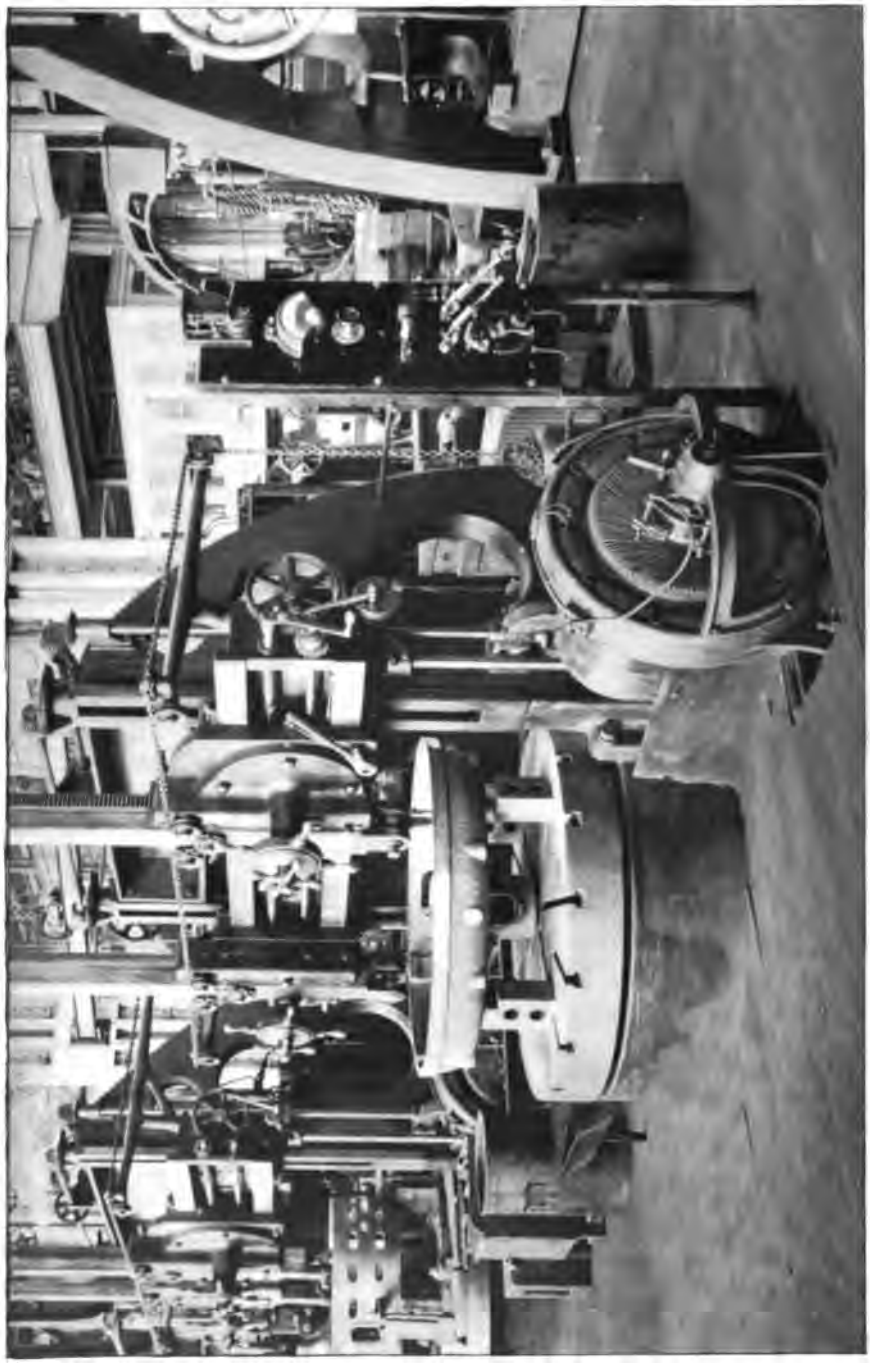
A LODGE & SHIPLEY LATHE DRIVEN BY A MOTOR MADE BY THE NORTHERN ELECTRICAL MFG. CO., MADISON, WIS., U. S. A.

secondary circuit connected with an external variable resistance.

Methods other than those described above have been devised to control the speed of induction motors for special purposes. The number of poles and speed of the rotating field may be changed by changing the connections of the primary winding. By this means the speed may be decreased inversely as the number of poles is increased. It has also been proposed to supply two circuits of different frequencies for the operation of the motors.

Finally it may be said that the polyphase induction motor with adjustable

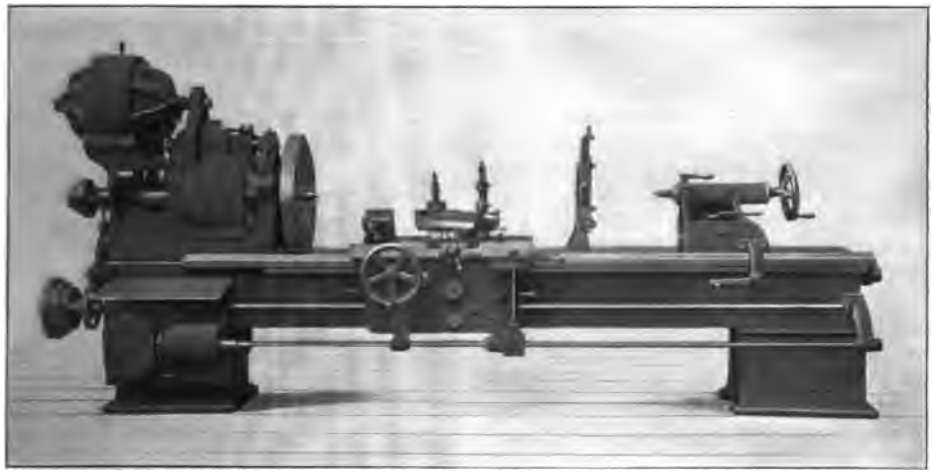
It may be of interest to sketch the equipment of a typical machine-shop, manufacturing, say, simple and compound engines, and having a total motor equipment of 1000 H. P. The generating plant would consist of two 250 H. P. compound condensing engines driving direct-connected two-phase alternators, delivering current of 25 cycles per second at 220 volts. The low number of alternations is chosen with regard to the speed and efficiency of small induction motors. The voltage is as high as safety permits in situ-



VERTICAL BORING MILLS BUILT BY THE BETTS MACHINE CO., WILMINGTON, DEL., U. S. A., EQUIPPED WITH ELECTRIC MOTORS BY THE GENERAL ELECTRIC CO., SCHENECTADY, NEW YORK, AND IN SERVICE IN THEIR SHOPS

ations where men are apt to come in contact with the conductors.

Most of the machine tools will be driven by induction motors of the squirrel-cage type, while hoists and elevators will be driven by motors having adjustable resistance in the secondary. If the latter class of service is very large and if, in addition, there are electric shifting locomotives and many tools requiring delicate speed regulation, double-current generators may be substituted for the simple alternators, thus permitting the use of direct-current motors for these purposes.



A 24-INCH MOTOR-DRIVEN LATHE MADE BY THE AMERICAN TOOL WORKS CO., CINCINNATI, OHIO, U. S. A.

The lighting in the shop will be done by incandescent lamps, operating on either phase of the alternating circuit.

The office and draughting room may be supplied from the same source, but if there are many machines making sudden and large demands for current, the light will be too fluctuating to be desirable for office use. In that case, the lighting current may be obtained from the small direct-current machines supplying current for exciting the alternator fields. The characteristics of the electrical equipment above described are those most important in a shop, namely, efficiency, simplicity, and reliability.

In view of the fact that the alternating and direct-current systems each have vigorous and uncompromising partisans, it may be well in conclusion to sum up their comparative advantages. As regards the generating plant, the alternating current system is decidedly preferable. An alternating-current generator, even including the exciter for the plant, is a simpler, more reliable, and generally a cheaper machine than a direct-current generator of the same capacity. The latter, with its costly and cumbersome commutator and brushes, must always be an object of care and attention, while the only moving contacts about an alternator are light brushes bearing upon simple slip-rings. If the direct-current system involves multi voltage distribution, the cost and complication of the generating plant are greatly enhanced.

The wiring will be the simplest for direct current distribution at one voltage. Next in order are the three-wire direct, three-phase, and three-wire two-phase alternating-current systems, followed by the four-wire two-phase alternating, and then by multi-voltage systems. If induction motors are employed, a higher voltage than with direct-current systems may be used with equal safety, thus reducing the cost of wiring.

The controlling apparatus used for induction motors often consists, with

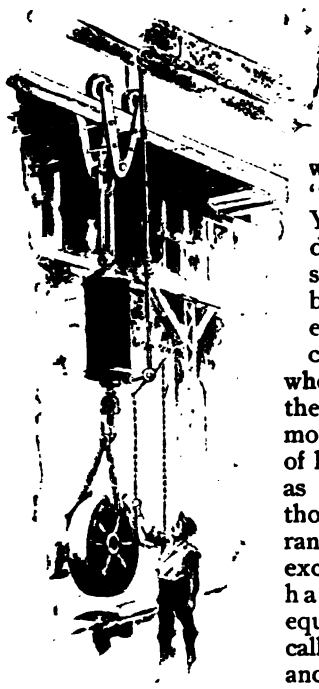
the constant speed type, of an ordinary switch, or for large motors starting under load, of a double-throw switch in connection with a small auto-transformer, which, as previously explained, is merely a coil of wire on an iron core. The variable speed induction motor is provided, in addition, with a rheostat. Controllers and starting boxes for handling direct-current motors usually include one or more switches, one or more rheostats, and often a commutator or multiple-point switch. All this apparatus, besides occupying much space, is, of course, liable to, and frequently does, get out of order The contacts wear or are burned away and demand frequent repairs.

The characteristics in regard to speed control of the several types of motors may be defined as follows:—The induction motor with squirrel-cage secondary and the direct-current shunt motor run at a nearly constant speed at any load. If the squirrel-cage secondary is exchanged for one in the circuit of which variable resistance may be introduced, and the shunt motor is provided with variable resistance in the armature circuit, these motors may be caused to run at any speed, but not with good speed regulation under varying load. In addition, the speed of the shunt motor may be varied by varying the field excitation or by supplying the armature from multi-voltage circuits, but in each case at a sacrifice of capacity. The series motor operates through a great range of speed and torque, but has no inherent speed regulation. In the matter of starting torque, it may be equalled by a properly designed induction motor having resistance in the secondary.

In simplicity of construction, and, therefore, in cost of attendance and repairs, the induction motor unquestionably takes first place. In general, it has no moving electrical contacts, while a direct-current motor requires a complex commutator, brushes, and brush holder. The commutator, especially when subjected to dust and dirt and when placed in unskilled hands, is a constant source of expense and trouble, requiring to be frequently cleaned, turned down, etc. The induction motor, on the other hand, is as simple in construction as a grind stone, and has nothing to wear out or to be looked after except the bearings. Except in the limited number of cases where delicate speed control is desired, it is, through its hardiness, unequalled for all purposes of electric power distribution.

CRANES FOR MACHINE SHOPS

By George L. Clark



THE great essential in cranes for the machine shop is mobility. The hoisting tackle is wanted, as they say, "all over the shop." Yet this ideal is often difficult or impossible of attainment, because of the presence of belting and countershafts. For wherever these are, they interfere with the movements of any form of hoisting tackle; and as they are present, though variously arranged, in all shops, excepting those which have been recently equipped with electrically-driven machines, and also in many of these where the sectional method of driving is adopted, the hoisting arrangements hitherto in use have been of a more or less incomplete and unsatisfactory character.

In order to understand the nature of the problem involved it is necessary to remember that the leading conditions which prevail in the various classes of machine shops are much diversified. The differences in this respect are very great,—between the heavy and the light machine shops, as well as in the belting arrangements. In some light shops no lifting tackle whatever is required; in many heavy shops loads up to forty or fifty tons or more have to be handled. The erecting shops, too, are very frequently intimately associated with the machine shop, being often included under the same roof, and then a similar range in lifting capacity is required, but uncomplicated by the presence of belting.

In very many machine shops until recently the pulley blocks afforded almost the only means of lifting, as they still continue to do with numerous firms. But though open to objection, these are not quite so wasteful of time as they appear to be, because their work is usually limited to lifting castings and forgings from a trolley into the machines, and vice versa. Now in a shop of considerable length the task of bringing the heavy work to, and fetching it from, the machines, is usually more laborious than that of lifting it into and out of the latter. Here the great value of narrow-gauge trolley tracks down the centre of a shop is evident. The gangway must, in any case, be left clear, and the tracks, therefore, do not encroach on ground required for other purposes.

Another reason why the pulley blocks have held their place so long is because often much time is occupied in the adjustment of work on machines,—less, of course, in lathes than in some other tools, and less when setting between centres than on a face-plate, in which often much time is occupied with the work slung up, while adjustments are being made with dogs or clips. To bolt work to any vertical face is generally a tedious job. But even on horizontal tables, when centres and edges have to be located exactly for drilling, planing, shaping, or slotting, adjustments are often very tedious, engaging the hoisting tackle for perhaps from fifteen minutes to an hour at a time. This illustrates the advantage of the practice of fitting some of the heaviest machines with their own cranes or swing arms.

A 6-TON, SINGLE-RAIL ELECTRIC CRANE, MADE BY MESSRS. CRAVEN BROS., LTD., MANCHESTER, ENGLAND

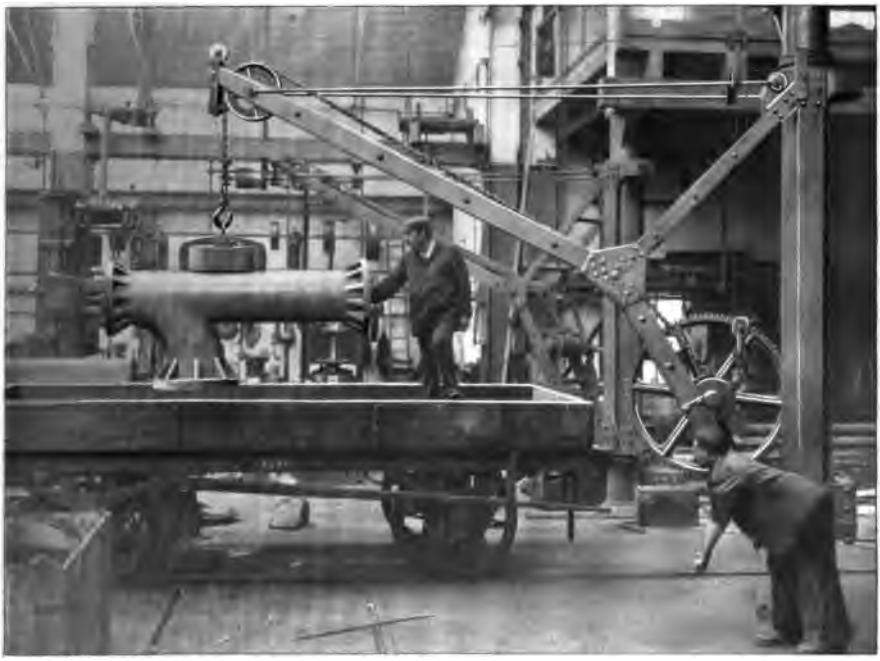
Having the work brought to the machine by trolley tracks, there is very little traverse of movement or height of lift wanted, and, therefore, quick-speed hoisting tackle is of comparatively less value than it is in foundries and boiler shops, where the distance of traverse and of lift are generally greater. But a form of tackle, like the pulley blocks, many sets of which can be distributed about the shop, while each one may be occupied for an indefinite period without hindering the handling of other work, has much to recommend it. Moreover, the exact adjustments which are obtainable with the pulley blocks are a very valuable feature, because massive pieces can be maintained just "floating" on the machine tables while their precise position is being located. Another point is the self-sustaining property of these blocks, which, without brake or care on the part of the attendant, maintain the load safely at any height.

The rivals to the block tackle are the light travellers, operated by dependent ropes or chains, swinging jib cranes, overhead power travellers, single-rail cranes, and light hoists running on overhead tracks. These all are adapted to certain conditions, the nature of which we will now consider.

The arrangements for driving machine tools, and the construction of workshops, and questions of power available, control, in a very great degree, the choice and location of hoisting tackle. Three leading systems of driving exist in shops. In one, the line-

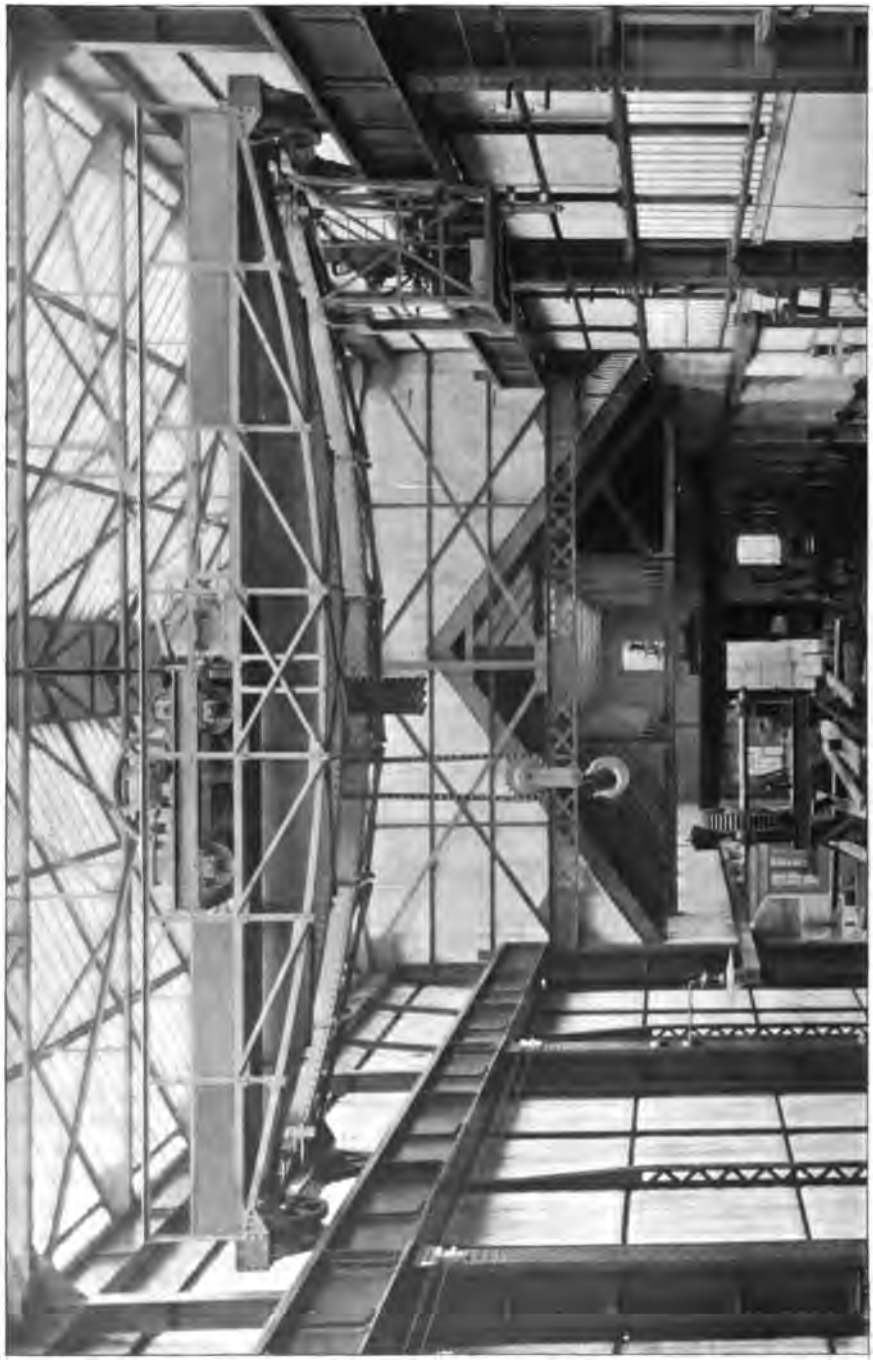
shaft runs along the centre of the shop, or the shop bay, as the case may be, and belts drive to the countershafts at the sides of the shop, or bay, whence the machines are belted. In another, the line-shafts run in side bays and drive to counters either in the main bay, or in the side bays in which the main shafts are contained. In the third, the drives are vertical, or slightly inclined, both from line to counters, and thence to the machines. The last is not an ideal drive from the point of view of belt efficiency. It is, however, frequent, and divides favour with the first design when there is but one shop bay, but it demands more head room than the others. It permits of the use of overhead travellers, vertically, which tends to slip and loss of efficiency, and also involves the necessity of tight fitting, which induces rapid wear and tear, both on belts and bearings. Having shop arrangements planned on these varied designs, we can see how hoisting machinery should be selected to suit each particular case.

With a line-shaft down the centre of the shop, in which no overhead traveller can be installed, pulley blocks are usually employed, as being best suited, on the whole, to the conditions. They may be either slung from the beams overhead, or they can be hung from a hook dependent from a light four-wheeled trolley running along the bottom flange of an I-beam, carried by the



AN ELECTRO-MAGNET LIFTING A 12-CWT. PIPE INTO A RAILWAY TRUCK AT THE WORKS OF THE SANDYCROFT FOUNDRY CO., LTD., CHESTER, ENGLAND

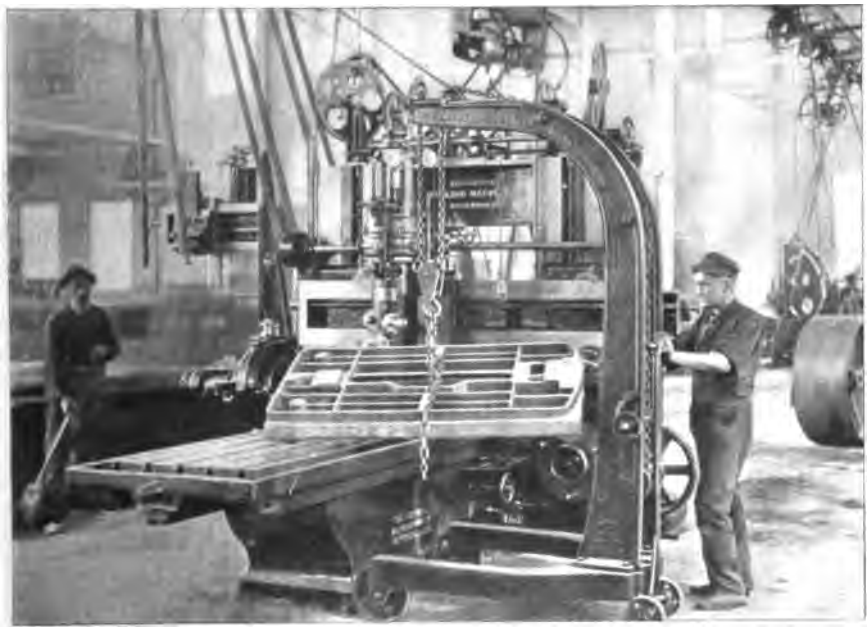
while a central line-shaft does not. But where a building is flanked by side bays the second arrangement is preferable, because it leaves clear room for the traverse movements of overhead travellers, while it is free from the objection of having the main belts driving nearly top flange on hangers suspended from the roof principals. There may be one or two tracks of these I-beams,—one down the centre, or two at the sides adjacent to the machines, the latter being the better arrangement. Instead of beams of I section, flat bars can be



A 25-TON, THREE-MOTOR ELECTRIC TRAVELLING CRANE MADE BY MESSRS. RANSOMES & RAPIER, LTD., LONDON

slung edgewise to carry two-wheeled trolleys running on the top edge. In such a case the floor trolley and its narrow-gauge line can be dispensed with, though these are desirable in any shop, no matter what forms of hoisting machinery are used. But the I-beam arrangement is not quite satisfactory unless the tracks are after the latest types of American design, with turntables and offshoot branches coming over the traveller happens to be held up for a considerable time with a piece of work that is being set, or in loading or unloading a number of forgings or castings that would otherwise block the gangway. Having the belting and counters kept snugly next the walls of the shops, or pillars of the machine bay, any type of crane can be installed.

The special recommendation of the traveller is its mobility, and the fact that

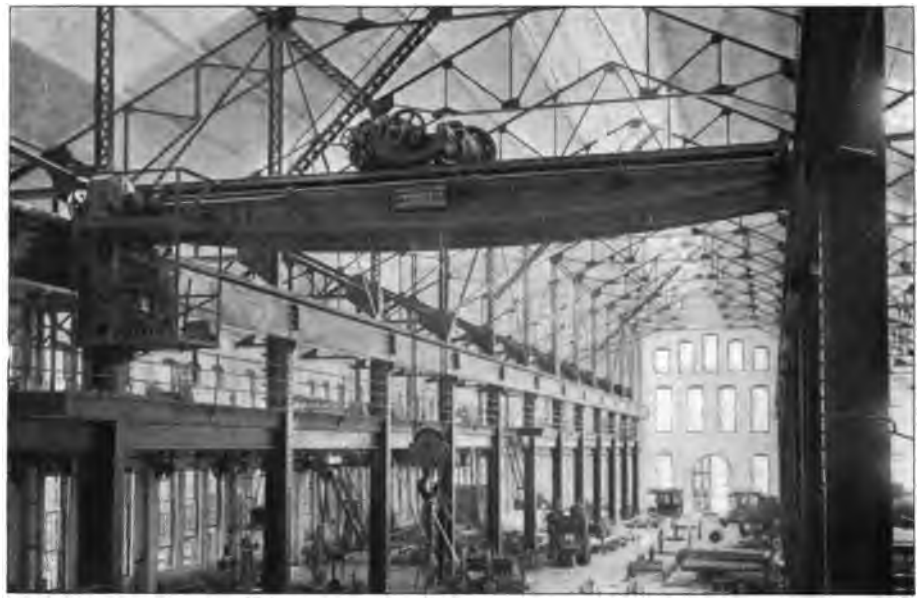


A PORTABLE CRANE MADE BY THE FRANKLIN PORTABLE CRANE & HOIST CO., FRANKLIN, PA., U. S. A.

heavier machines at least, and serving nearly all the shop area.

The other two arrangements of belting exist now in nearly all shops. They do not interfere with the employment of overhead travelling cranes, which, in conjunction with a narrow-gauge track down the centre of the shop, help to make up the plan which is, on the whole, preferable to any other, and one that is being installed more than hitherto. This by no means dispenses with the use of pulley blocks or of swinging jib cranes, which are still retained for occasional service for special groups of machines, or are employed when the it covers the entire area of the shop, so that work can be picked up from anywhere and set on any machine. This cannot be done so readily with any other hoisting device. The hoisting speeds need not generally be so high as those used in foundries and boiler shops. The question of rates of travelling and traversing are, in the main, governed by the lengths and widths of the shops.

A handy arrangement for hoisting in the smaller machine shops is an improved form of the old single-beam traveller from which differential or other blocks are suspended on four-wheeled trolleys. This is better in some respects



A 15-TON, 37-FOOT SPAN ELECTRIC TRAVELLER IN THE NORTHERN PACIFIC RAILROAD SHOPS AT BRAINERD, MINN. INSTALLED BY THE WHITING FOUNDRY EQUIPMENT CO., HARVEY, ILL., U. S. A.

than the overhead tracks already mentioned, because it is able to cover every inch of the shop area that is included between the length of the runways and the length of the I-beam, while the tracks can cover but certain portions of the shop, and, to be of value, must be arranged in relation to the machines laid down. An objection to the single-beam travellers is risk of cross working on the rails. This must be guarded against by having a fairly long wheel-base and by leaving very little play between the wheel flanges and the rails. It is better also to make the wheels double-flanged than single.

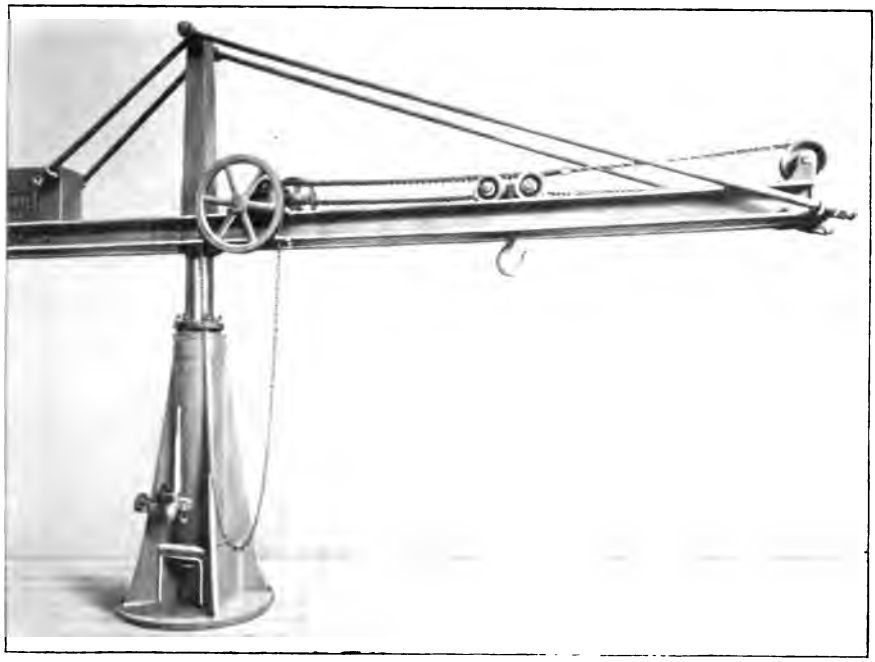
In many shops in the North of England and in Scotland the single-rail crane is a favourite form of hoisting machine for the heavy departments. This crane runs down the centre of the shop, on a single rail below and between guide rails above, and its jib swings in a complete circle, commanding the machines on each side of its track. It is an excellent and most useful crane, and though it occupies the middle of the shop, it blocks only that part of the gangway which it happens to occupy at any one time. It does not interfere with narrow-gauge tracks laid down alongside its rail.

The older cranes of this class were operated by hand, later ones by cotton rope, and recently the electric motor has been applied to them. The driving and guide pulleys for cotton rope are at the top of the post, where the current also is taken in the case of electrically-driven cranes. Both kinds are eminently suitable for heavy machine shops. Although there is no racking motion, the combined movement of the crane bodily and the slewing of the jib produce that result. Travelling, slewing, and hoisting are performed from one standpoint. These cranes are very popular in locomotive shops.

Either an overhead or a central-rail system can be supplemented for the service of the heavier machines by swinging wall jib cranes, which may be operated by any agency as most convenient, by hand usually, or hydraulic power. These are often swinging jibs only, which carry a trolley for pulley

blocks. Such cranes and the machines which they serve must be mutually arranged with regard both to radius covered and power, and should, when possible, serve not less than two adjacent machines. The time occupied in fixing work is usually small by comparison with that occupied in tooling it, and things can, therefore, be generally planned so that the necessity for fixing work on two adjacent machines shall not clash at the same time. In one design there is a swinging jib fitted with a hydraulic lifting cylinder and multiplying chain. The cylinder trolley runs along the jib, and is supplied by a jointed pipe. Such a crane is useful in the machine, as in the plating and boiler, shop. Cranes of this type are made in powers from half a ton to five tons, with a lift of from 4 to 5 feet, and radius of 20 feet.

Portable jib cranes of the balance type are of value in shops that deal with heavy work and in which the belt arrangements do not permit of the unrestricted movements of an overhead traveller. Their value is, however, greater in yards for bringing in castings, forgings, plates, and other work to the shops. The illustration on page 108 shows a crane of this class by Messrs. Fielding & Platt, Ltd., of Gloucester, England, in which the hoisting is effected by hydraulic power, the lifting cylinder being enclosed in the post. The travelling is done by hand through spur wheels and the slewing in a complete circle by pulling around at the load by hand. A portable riveter is shown slung in the crane with its jointed pipe connection,—one of its useful applications.

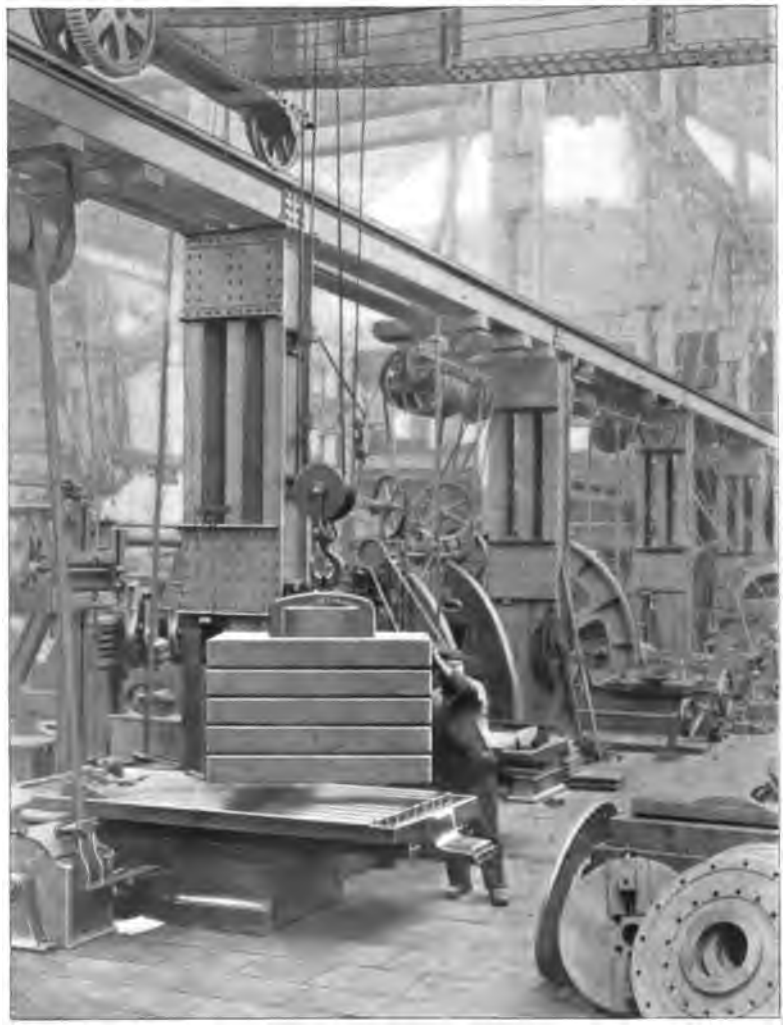


A DIRECT-ACTING HYDRAULIC CRANE MADE BY MESSRS. RICE & CO., LTD., LEEDS, ENGLAND

Here another type of single-rail crane, shown on page 115, a design also of Messrs. Fielding & Platt, Ltd., made specially for their hydraulic riveters, may be noted. The value of this crane is that it occupies practically no floor space, running on rails on the floor, or on brackets attached to the walls, and guided above by a top rail. Walking

A 39-FOOT SPAN, 25-TON ELECTRIC CRANE WITH A 5-TON AUXILIARY HOIST. INSTALLED IN THE BABCOCK & WILCOX COMPANY'S NEW SHOP AT BAYONNE, N. J., BY THE CRANE DEPARTMENT OF THE NILES-BEMENT-POND CO., PHILADELPHIA, PA. THE CRANE IS HERE SHOWN CARRYING A 66-INCH BORING MILL

WESTINGHOUSE ELECTRIC MOTORS APPLIED TO A 30-TON TRAVELLING CRANE



AN ELECTRO-MAGNET, CONNECTED TO AN OVERHEAD TRAVELLING CRANE, LIFTING A CASTING, WEIGHING 32 CWTS., FROM A PLANING MACHINE AT THE WORKS OF THE SANDYCROFT FOUNDRY CO., LTD., CHESTER, ENGLAND

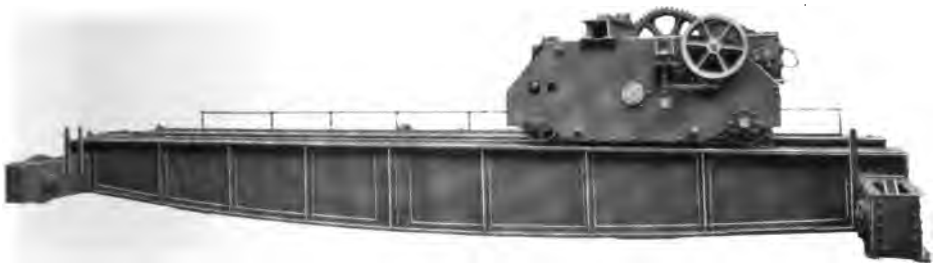
pipes transmit pressure to the crane and its jenny, and the lift is direct by the cylinder, seen between the struts. The capacity is from one to two tons lift, through 4 feet high and 20 feet radius.

A portable crane by the Franklin Portable Crane & Hoist Company, of Franklin, Pa., U. S. A. (page 97), has the very good feature that it can be taken anywhere in and about the shop independently of any system of rails, for it runs on plain wheels. Stability is provided for by the bent camlike shape of the front axle, which is pressed down on the ground when the draw handle is lifted up. The crane is operated with hand gear, the jib is arched, and the lift is from two to three tons. It is as useful an appliance in the machine shop destitute of tracks as the smooth-wheeled trolleys are on which work is run in and out. It can be drawn up to a machine, work can be taken off, and

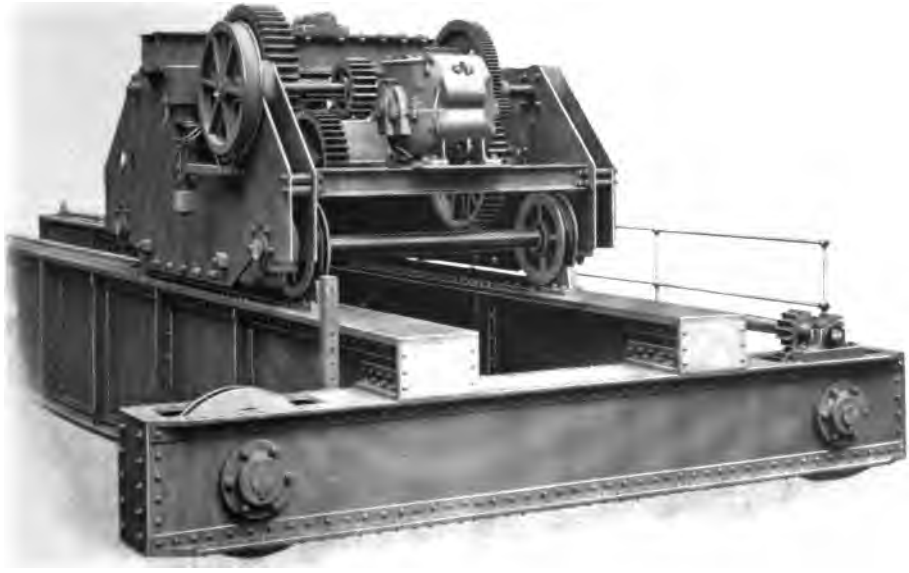
the crane then drawn to any part of the shop, or out of it, if necessary.

Unfortunately, ideal arrangements of hoisting tackle are frequently impossible, because of the way in which shops have often been laid out, or developed without any proper, predetermined plan. Big machines and little ones are too often confusedly intermixed, the latter having generally been so placed because small spaces between the big ones, in a too cramped area, offered themselves invitingly. Hence the irregularity of arrangement which characterises so many shops, and which utterly precludes the possibility of effecting a due correlation between the hoisting machinery and the tools so grouped together in a higgledy-piggledy fashion.

When laying out machine shops anew the tools and cranes should be mutually arranged. The smallest machines require no aid from tackle of any kind and the proper place for these is entirely apart from the heavy ones, in side bays, or in galleries. And there is no objection to running the line-shafting along these flanking bays which contain the light machines, thus leaving the main shop with the heavy tools clear for the service of an overhead traveller or travellers, or for tracks, single-rail cranes, or jib cranes. In many large



A 60-TON, THREE-MOTOR ELECTRIC TRAVELLER OF 60 FEET SPAN, BUILT BY MESSRS. HENRY BERRY & CO., LTD., LEEDS, ENGLAND



AN ENLARGED VIEW OF THE CARRIAGE

A TWO-MOTOR, 3-TON ELECTRIC HOIST FOR OUTDOOR SERVICE IN CONNECTION WITH MACHINE SHOPS
THIS HOIST HAS SWIVEL TRUCKS TO TAKE A CURVED I-BEAM WITH RADII OF NOT LESS THAN
10 FEET. BOTH HOISTING AND TROLLEY TRAVEL CAN BE DONE AT THE SAME TIME
OR SEPARATELY. MADE BY MESSRS. PAWLING & HARNISCHFEGER,
MILWAUKEE, WIS., U. S. A.

shops arranged on good lines in which the machines of a certain class are often grouped together,—sometimes, though not necessarily, in different buildings, or under the same roof,—the proper plan is to keep the heavier machines towards one end of the group, and the lighter ones towards the other, so favouring the work of the most economical installation of the cranes.

It follows from the foregoing considerations that it is not possible to say off-hand what are the best arrangements of cranes for all machine shops, but that each case must be treated individually. That which is best for one may be the worst possible for another. And when laying out new shops the question of hoisting tackle must be considered in direct relation to the location and capacity of machines.

In the foregoing remarks the question of types of cranes alone has been treated, leaving that of the agencies by which they are operated for separate consideration. The agencies in present use are hand power, steam, water, air, and electricity, the last two being of comparatively recent growth.

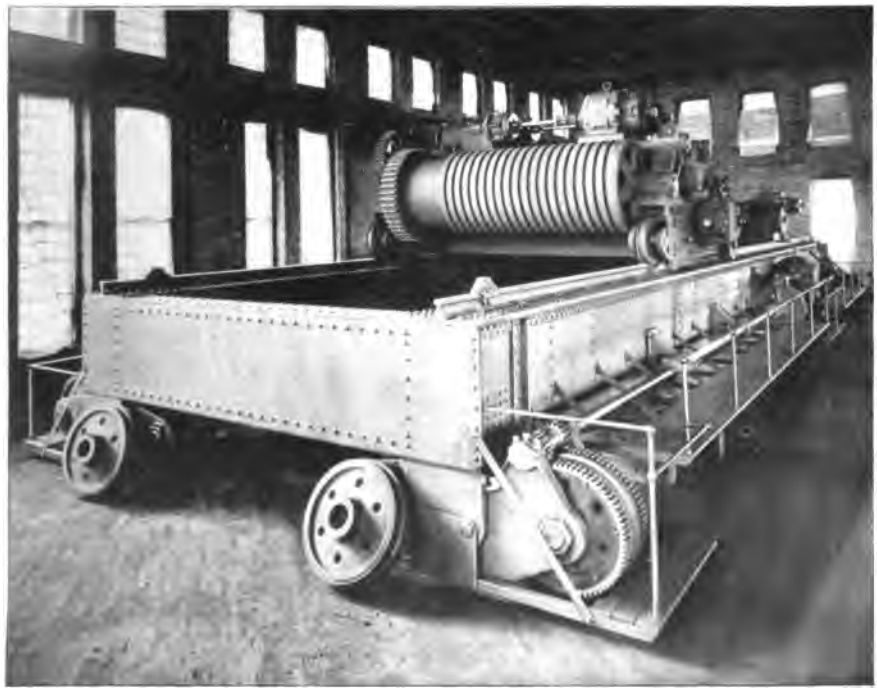
The useful place filled by the hand pulley blocks has been stated, and excepting in shops which are fitted with a very complete installation of other tackle, they cannot be dispensed with. For the same reason swinging-jib wall cranes from which pulley blocks are suspended, or which are operated by single-purchase hand gear, are very serviceable for the command of the heavy machines. In a shop of no great length, containing but a few heavy machines, an overhead hand traveller is a very suitable mechanism to employ, and its runways need not go beyond the heavy machines if they are grouped by themselves, since light machines do not need the services of a traveller. We have here, therefore, a number of

examples of the utility of hand-operated cranes and tackle in machine shops, old and new.

Turning to the power cranes, nothing can be said in favour of steam travellers for machine shops. The sulphur from the coke fire in the boiler, and the dust from the chimney and from stoking up, are fatal to the cleanliness of machines and to the wholesomeness of the atmosphere. In lofty erecting shops, destitute of machinery, these objections do not count for so much, but they nevertheless tell against the use of steam. The place for steam cranes is out of doors, not inside buildings.

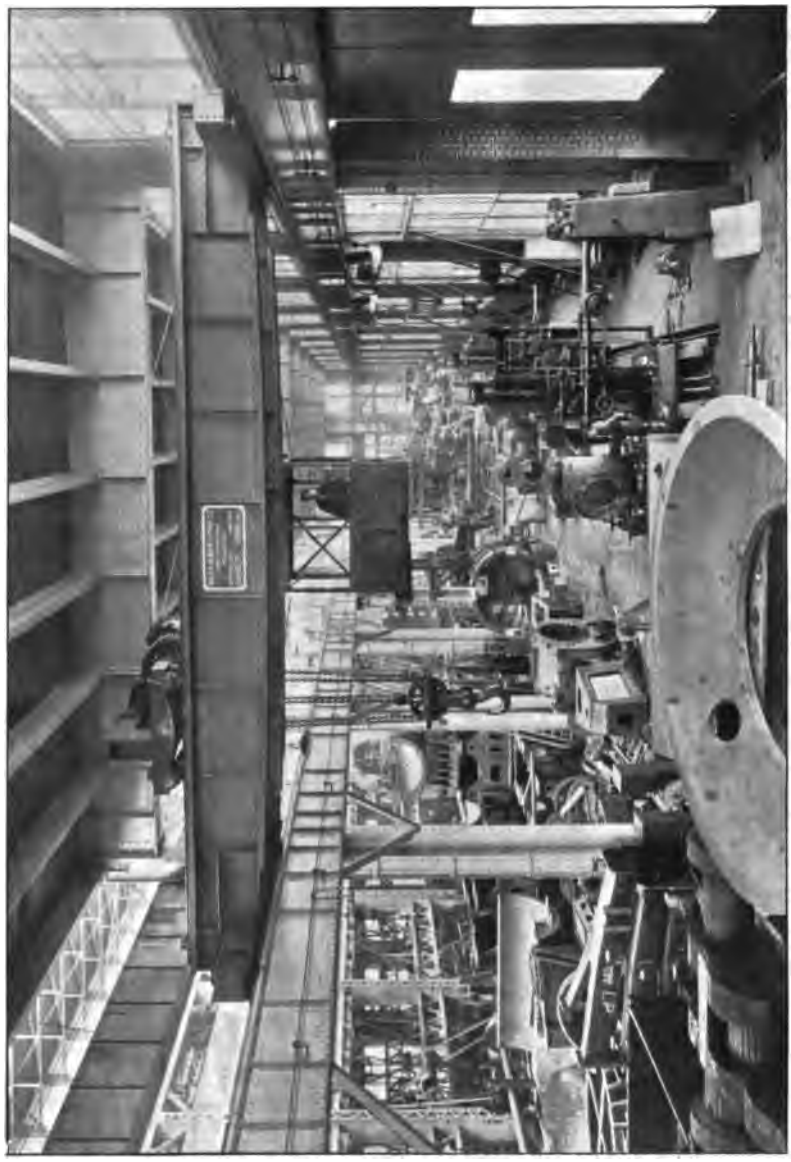
Fixed steam jib cranes, to which the steam is brought in pipes from a boiler outside, are not so objectionable: but since there are better operating agencies than these, a firm would not be well advised to put down such cranes in new shops. Hydraulic wall cranes of the swinging-jib type are very suitable for serving the heavier machines. Noiseless, capable of precise regulation, easy in movement, they should supplement the work of the travellers in any shop where water power is installed.

We are thus left with the two newer agencies,—air and electricity. There are also two other systems,—the square shaft drive, which is out of date for machine shops, and the cotton-rope drive, which, though operated by a steam-engine, represents, nevertheless, for all practical considerations, a system distinct from the travellers and cranes actuated directly by steam power.



A 150-TON HIGH-SPEED ELECTRIC TRAVELLER, WITH A 25-TON AUXILIARY TROLLEY. BUILT BY MESSRS. PAWLING & HARNISCHFEGER

The special value of the air hoists lies in the handling of loads of a few hundredweights chiefly. In order to secure the fullest advantages from this system, it is necessary to lay down a complete installation of overhead tracks. Having a compressed air plant in a factory, it is easy to make connection with flexible hose to the direct-acting hoists at



A 38-FOOT SPAN, 30-TON CRANE IN THE SHOPS OF THE WM. CRAMP & SONS' SHIP AND ENGINE BUILDING CO., PHILADELPHIA. INSTALLED BY THE CRANE DEPARTMENT OF THE NILES-BEMENT-POND CO., PHILADELPHIA, PA.

any location of the tracks over lathes and other tools. The system provides that mobility which is so desirable in handling work in and about the machines.* It is also easy to convey air to hoists suspended from, or travelling along, the jibs of swing cranes. For these reasons the compressed air system is one that is certain to grow in favour.

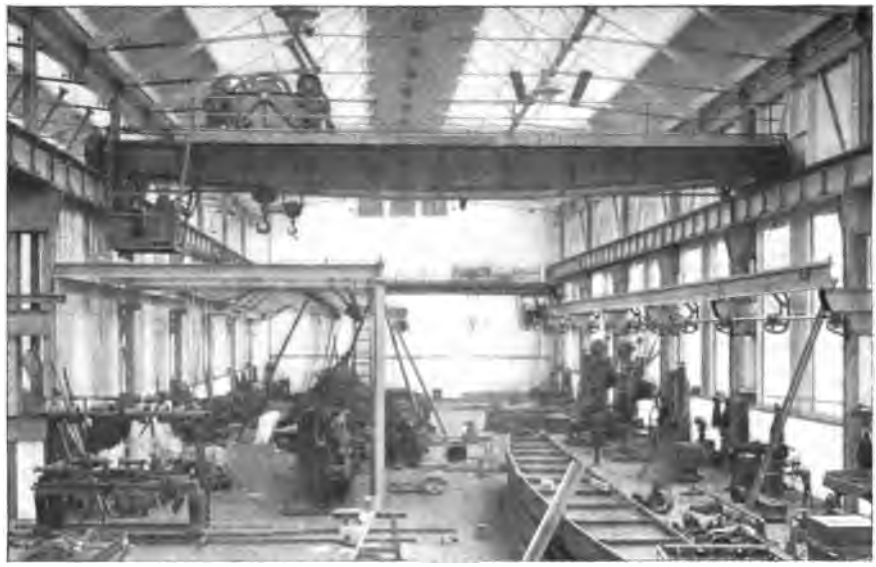
AN ELECTRICALLY-DRIVEN CRANE EQUIPPED AND INSTALLED BY MESSRS. CROMPTON & CO., LTD., LONDON, AND THE CHATTERIS ENGINEERING WORKS CO., CHATTERIS, CAMBS.

Its reputation has suffered a little because some air hoists have been uncertain in action, jerky, and incapable of very precise regulation of their movement, due primarily to the highly elastic nature of the medium employed. But with later improvements in construction, and with methods of governing by oil the hoists have grown, and are increasing in favour.

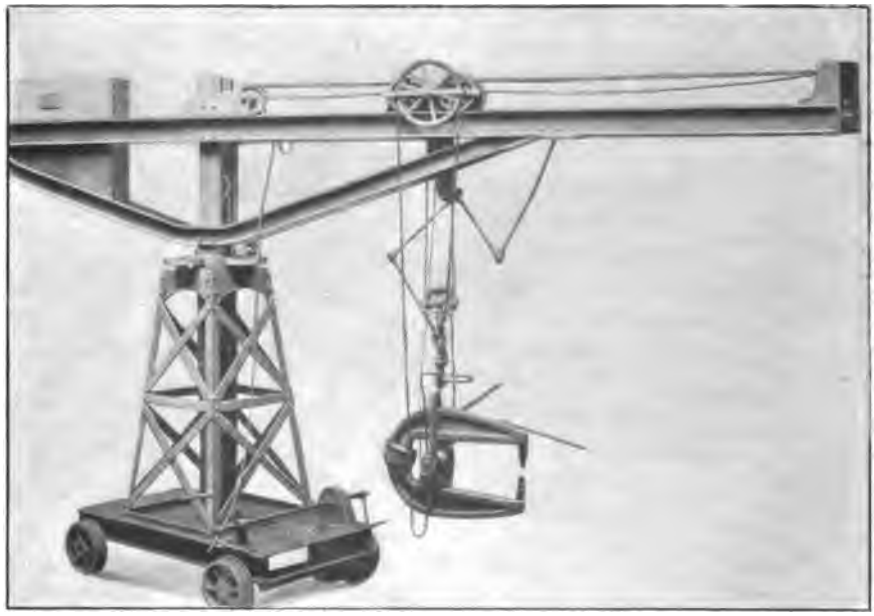
But the value of this track system is not quite so great in the machine shop as it is in the foundry, because many machines can be so excellently served with hand or power hoists slung overhead from a beam or joist, or trolleyed on a jib, the work being brought thither and removed therefrom either on a narrow-gauge track, or on shop trolleys drawn by labourers. The latter system, by the way, is not wasteful of time, while it has this advantage over rail tracks, that the trolleys can be run close up to the machines and between and around them; while in using the rails the work has to be taken from them and got to the machines located off the lines.

We now come to electricity, the newest and the most promising source of power. As yet, it is more especially fitted to two types of machine shop cranes,—the overhead traveller and the single-rail type. There are others as well, such as jib cranes and electric hoists and blocks, but the most familiar are the first-named examples, at present, of its successful use. The special

* Illustrations and further particulars of air hoists and travelling cranes operated by compressed air will be found elsewhere in this issue in an article entitled "Compressed Air in the Machine Shop and Foundry."—THE EDITOR.



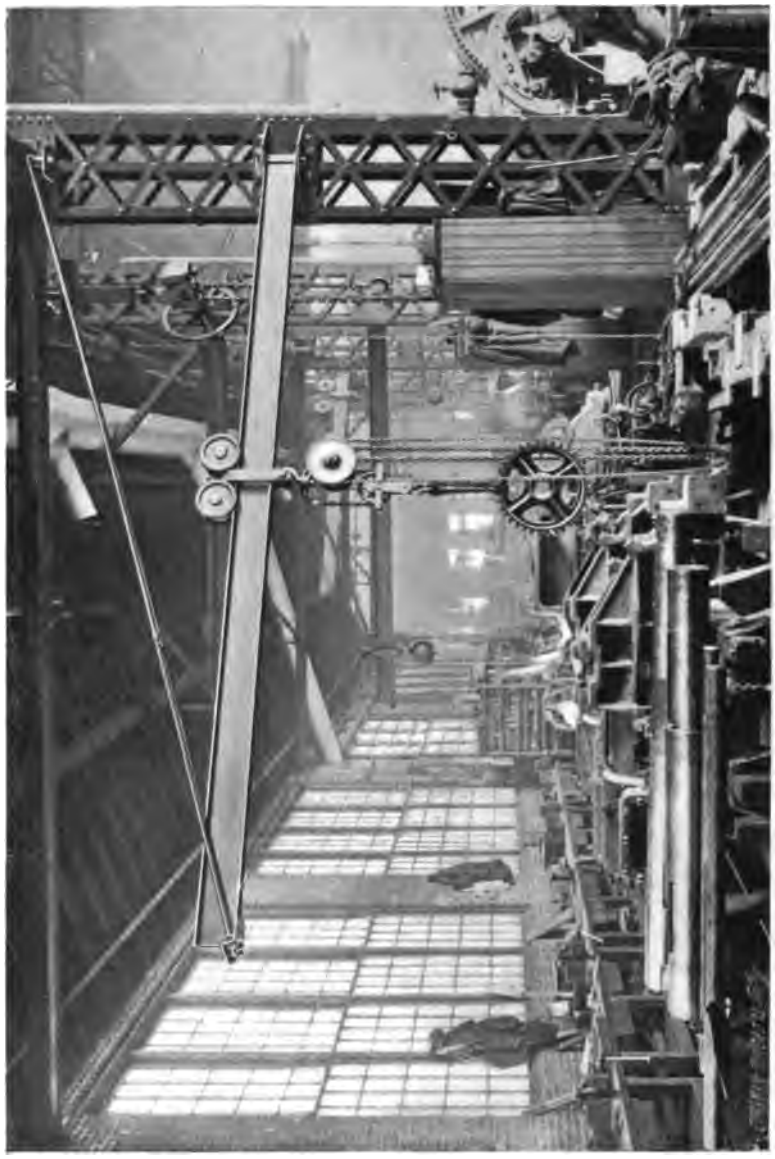
HERE A 10-TON TRAVELLER ON RUNWAYS OF LIMITED LENGTH IS PLACED BENEATH THE MAIN RUNWAYS OF THE LARGER, 25-TON CRANE SEEN IN THE FOREGROUND



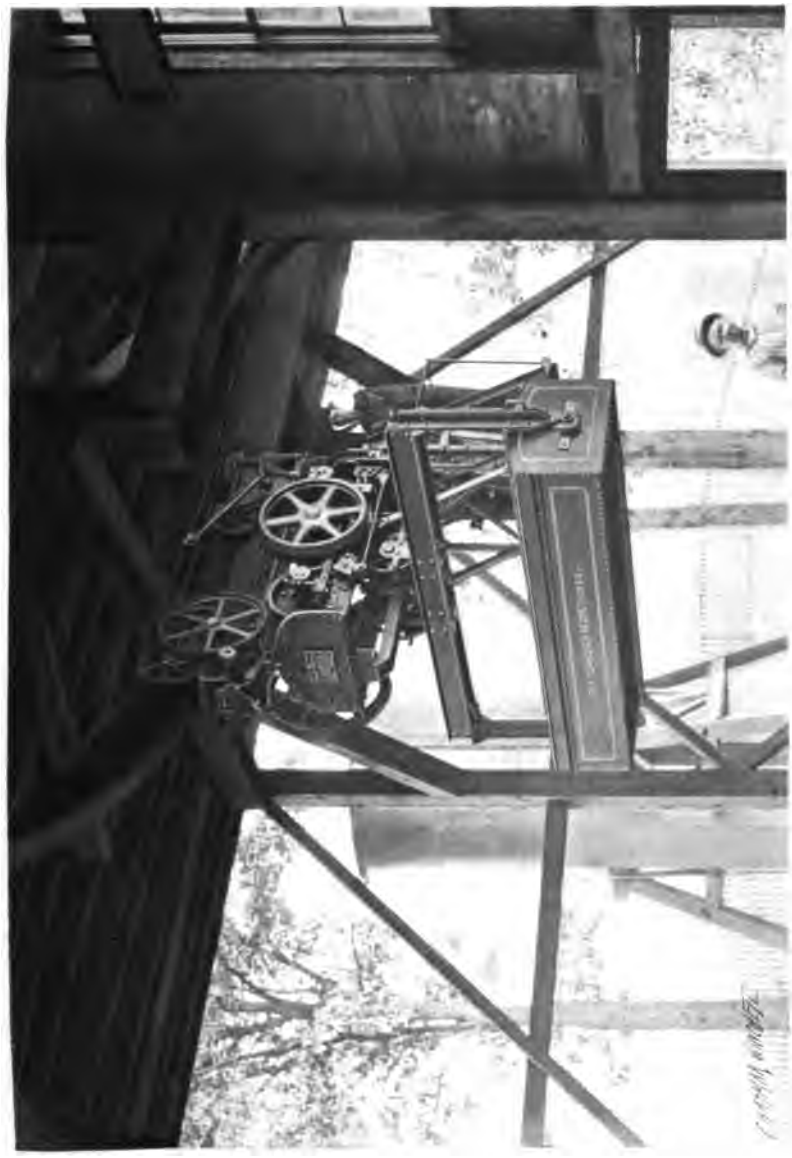
A PORTABLE HYDRAULIC JIB BALANCE CRANE, MADE BY MESSRS. FIELDING & PLATT, LTD., GLOUCESTER, ENGLAND

merits of the electric traveller are now pretty well known, such as the fact that no power is wasted when the crane is not in actual service, and that the power of each separate motor is exactly proportioned to the work which it has to do, and experiments have proved that there is a wide difference in the power that is absorbed in lifting, travelling, and traversing. Another good feature is the simplification of the movements, since there is less gearing in an electric traveller of modern type than there is in the steam traveller, or the square shaft, or the cotton-rope traveller, or the single-motor traveller. Moreover, the electric traveller, as now turned out, is a better made machine than its predecessors. The high speeds of motors and of motor gears render high-class workmanship imperative, and these cranes, therefore, run more smoothly and quietly at high rates than less modern cranes do at much lower rates. These facts, apart from minor other considerations, are sufficient to account for the growing esteem in which these cranes are held, as evidenced by the number of shops that have, and are having, them installed. And in high-powered cranes the fitting of an auxiliary hoist with its own separate motor for light loads effects a still further economy and renders the traveller economically adaptable to a very wide range of service. The auxiliary hoist is the latest solution of the problem of handling maximum and minimum loads in the machine shop. It is solved in two ways. The common travelling cranes handle heavy loads; light loads are lifted by other appliances, as hoists, pulley blocks, and swing cranes. From some points of view it is more convenient and economical not to multiply the hoisting tackle in this way, but to employ two distinct sets of gearing or two drums on one traveller, one set for dealing with a few hundredweights, or two or three tons, at high speeds, and the other for heavy loads at corres-

A 3-TON PORTABLE ELECTRIC CRANE EQUIPPED AND INSTALLED BY MESSRS. CROMPTON & CO., LTD., LONDON, AND THE CHATTERIS ENGINEERING WORKS CO., CHATTERIS, CAMBS.



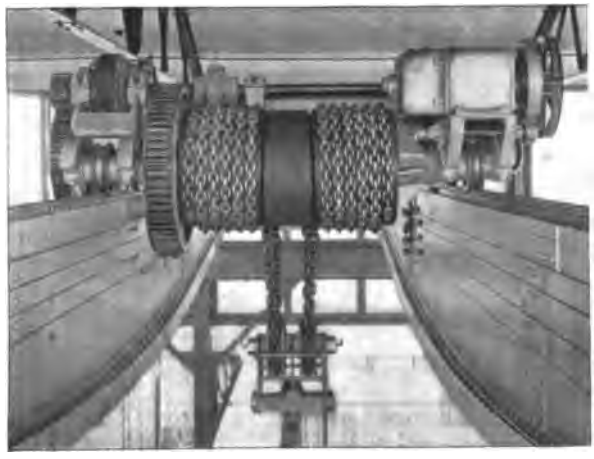
A JIB CRANE MADE BY THE BROWN HOISTING MACHINERY CO., CLEVELAND, OHIO, U. S. A., AND LONDON.



A 5-TON ELECTRIC TRAMRAIL AND TROLLEY SYSTEM, INSTALLED BY THE BROWN HOISTING MACHINERY CO.

AN ELECTRIC TRAVELLING CRANE BUILT BY THE CASE MANUFACTURING CO., COLUMBUS, OHIO, U. S. A.

pondingly slow speeds. These, in the best modern designs, are driven by separate motors, suitably selected for their particular duty. For the germ of this arrangement the electric traveller is indebted to the cotton-rope traveller, which is fitted with separate gears and barrel for light and heavy loads, and to some cranes fitted with extra hand gear for occasional light service. The auxiliary hoists of travellers lift sometimes in single chain; sometimes with a snatch block, as when loads exceed from one to two tons. Shops of great length cannot be served adequately by a single travelling crane only, in which case frequent recourse must be had to other supplementary tackle. But the present practice seems to be in favour of increasing the number of travellers to cope with all requirements. In locomotive shops there is another reason for this, namely, the bringing together of the combined power of the cranes to operate jointly in lifting a complete locomotive. When these are fitted with auxiliary hoists also, they are able to cover the whole range of work in the shop. Another favourite plan is to put in light travellers to supplement a single heavy one. These are often of the dependent hand-rope or chain-operated types, localised in certain parts of the shops over light machines or benches. Their runways are lower than those of the main traveller. We may anticipate that these will gradually be displaced in live shops by small electric travellers, or electric hoists. The illustration on page 108 shows an electric traveller of 30 feet span and ten tons capacity on runways of limited length, placed beneath the main runways which



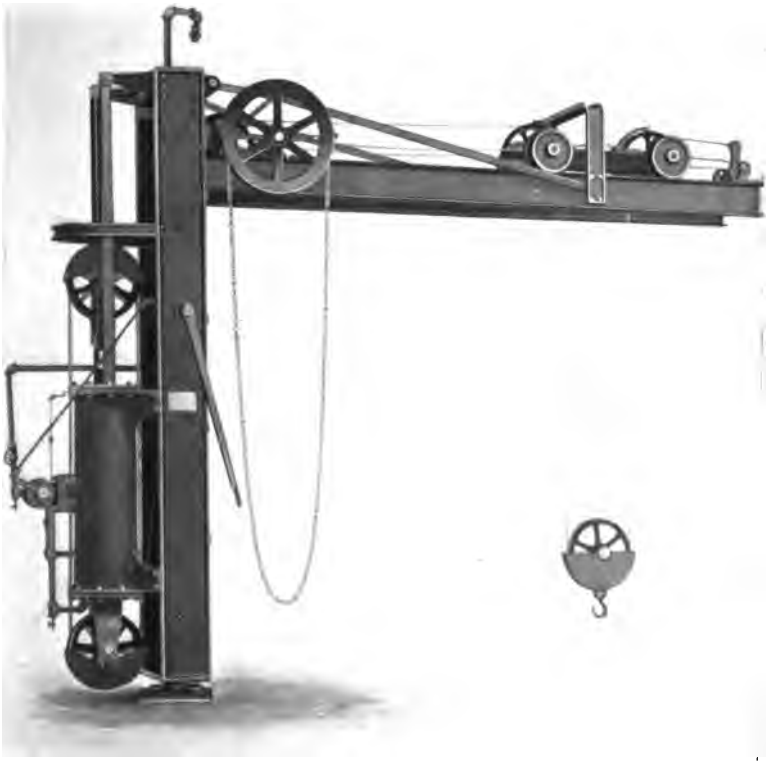
THE CRAB OF THE CASE CRANE ABOVE

carry the twenty-five-ton traveller seen in the foreground. The view given is that of one of the bays of a new machine and erecting shop recently started by the makers, Messrs. Craven Brothers, Ltd., at the new works extension at Reddish, near Stockport, England.

Similar good reasons favour the application of electricity to the single-rail crane as to the travellers. The hand-operated single-rail crane is better than nothing, and it has filled a useful place. But its retention can hardly be recommended in face of the higher utilities of the cotton-rope drive and of the electrical conductor, and though this has long been a favourite form, there can be little doubt that it will disappear in time, displaced by the overhead traveller that occupies no floor space whatever.

The wonderful adaptability of the electric drive is seen in these and other strong contrasts. The mysterious current is equally suited for lifting a hundredweight or two, or the greatest masses to be handled in the big modern shops. There are recent examples of overhead travelling cranes lifting 150 tons maximum. One of these, by Messrs. Pawling & Harnischfeger, of Milwaukee, Wis., U. S. A., lifted 200 tons as its test load. Its total weight is over 169 tons. A view of this crane is given on page 105.

The cotton-rope drive remains to be considered. It is, with the exception of the electric drive, the best system yet installed for operating travellers and single-rail cranes. Though not free from objections, these are of far less

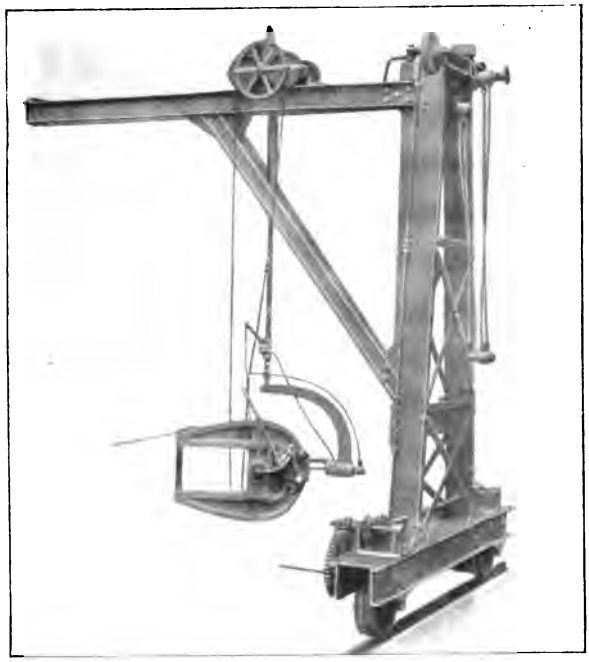


A QUICK-ACTING STEAM, HYDRAULIC, OR AIR JIB CRANE, WITH VERTICAL CYLINDER. FROM 1 TO 5 TONS CAPACITY. MADE BY THE BROWN HOISTING MACHINERY CO.

TWO 35-TON, FOUR-MOTOR ELECTRIC TRAVELLING CRANES, WITH AUXILIARY HOISTS, IN THE SHOPS OF THE LANCASHIRE & YORKSHIRE RAILWAY AT HORWICH. BUILT BY MESSRS. CRAVEN BROS., LTD., MANCHESTER, ENGLAND

moment than those which may be urged against the use of the square shaft, or of steam direct. The breakage of ropes, which is the most serious drawback, is one that is largely traceable to carelessness, to the use of pulleys too small, neither properly turned nor balanced, to bad splicing, and to neglecting to observe the beginnings of fraying-out. If these things are attended to, and a spare rope is kept in stock, the risk of broken ropes and delays for resplicing are reduced to a minimum.

The arrangements for changing the direction of drive and for operating the various movements from it are rather complicated, and are open to some objection. They certainly lack the simplicity of the all-electric-driven crane. But they appear worse than they really are, for the question is largely one of quality of workmanship; hence the good cranes of this type are a specialty in the hands of but a few firms. Watching these cranes in operation,—and there are an immense number in British shops,—the smoothness and ease with which they work is very pleasing, and for this reason some firms who have become accustomed to them still prefer to give repeat orders rather than install electric travellers. When a firm is not equipped with electrical generators, there is no doubt that the cotton-rope traveller and the single-rail type are superior to any others.



HYDRAULIC SINGLE-RAIL CRANE ARRANGED FOR MACHINE RIVETING. BUILT BY MESSRS. FIELDING & PLATT, LTD., GLOUCESTER, ENGLAND

Outside these various cranes there are more recent types, qualified to do valuable work in the machine shop, and the adaptability of which thereto may be suitably considered in conclusion. The special value of these lies in the rapid handling of work by power,—of a few hundredweights chiefly,—loads which predominate in the average shop.

The overhead trolley system is destined to fill a much larger place in the future than it does even at present, for little of it is yet seen in British shops, and British crane makers do not seem in any hurry to take up the manufacture. Yet the elements of the system are old, for the I-beams, suspended from principals, and carrying on the bottom flange trolleys for common pulley blocks, were used long ago in British shops. But this is crude, clumsy, and slow alongside the later and recent American devices. The leading features of some of these have been previously illustrated and explained in this magazine.

A large family of hoists is that in which air is employed for their operation, in place of the hand, hauling at a chain or rope. Some of these hoists are of the differential type; others are not, but are fitted with brakes. Their advantage lies in the vastly increased

A THREE MOTOR ELECTRIC TRAVELLING CRANE MADE BY THE NORTHERN ENGINEERING WORKS, DETROIT, MICH., U. S. A.

rate of lifting. Thus, an air-operated differential hoist by the Empire Engine & Motor Company, of Orangeburg, N. Y., U. S. A., will lift from 12 to 13 feet a minute. A foot a minute would be near the mark for a hand hoist. Using a brake, hoists are made to lift from 28 to 36 feet a minute. In all other respects the hoists take the places of the hand types, being attached to a chain, or running along overhead tracks. The Little Giant type of pneumatic motor, shown on page 21, in connection with the article on "Compressed Air in the Machine Shop and Foundry," lifts at the rate of 5 feet a minute, and is made to be hung over machines.

AN ELECTRIC HOIST FOR THE RAPID HANDLING OF LOADS UNDER 5 TONS. MADE BY THE SPRAGUE ELECTRIC CO., NEW YORK

There is no doubt that the light electric hoist is destined to fill a very important place in the machine shop, in which it is, as yet, rather a novelty, except in some of the most progressive shops. It is controlled by dependent cords from the floor, and is under as perfect control as the differential blocks are. It is drawn along the runways either by hand or by a separate motor. Messrs. Pawling & Harnischfeger, of Milwaukee, make a specialty of such

hoists in a very compact and handy form, in which hoisting is performed either with sprocket wheels or with drums. (See page 104.) The first is not recommended for any but hand-operated hoists. The drums are turned and grooved, and the gear wheels are cut, and the motor and controller are compactly arranged, with the drum, beneath the trolley framing, the wheels of which run on the lower flanges of the I-beams that are arranged, as required, over the machines.

Finally, the electromagnet, the latest development, will occupy a useful place in the machine shop, as it is already doing in the steel works and the plate yard. This does not affect the question of hoisting tackle directly, but that of slinging. The magnets can be attached to hoists, travellers, or any other cranes. In the case of travellers the man in the cage has charge of the operating switch. The time occupied in slinging work is a serious item, particularly with pieces of awkward shape, and the slinger has to be a man of some judgment. Slinging is often, besides, a two-man job, and the time spent is not inconsiderable, because some pieces have to be properly balanced; in others slip has to be guarded against; in others pressure on fragile portions has to be avoided by a careful disposition of the sling chain, or by using ropes, or by packing. By contrast with these the simplicity of the magnet and its instant grip has much in its favour. The illustrations on pages 95 and 102 show such magnets used by the Sandycroft Foundry Company, Ltd., of Chester, England, lifting a cast-iron pipe weighing 12 cwt. where the surface contact is but slight, and also lifting a casting weighing 32 cwt. from a planing machine table. These magnets are, in both cases, of 20-cwt. nominal capacity, using about 150 watts. As the magnets are energised from the storage battery lighting circuit, there is no risk of sudden failure of current.

When machine tools are driven electrically the same agency will be nearly universally employed for driving the cranes. Everything is tending thus. Other types will linger,—survivals from the past,—but electric travellers, hoists, and cranes will dominate them all.

A NEW SYSTEM OF REWARDING MACHINE SHOP LABOUR

THE LATEST ADVANCE IN THE ART OF SHOP MANAGEMENT

By H. L. Gantt

A KNOWLEDGE of physical science and mathematics has been for many years acknowledged to be of great benefit to the engineer, but it is only recently that the extreme importance of such knowledge has been recognised. There was a time, not long past, when the only requirement of an engineering structure was that it should not fail, and, of a machine, that it should perform the work required of it. To-day sharp competition has brought about a different condition of things.

A limiting factor in all engineering work is the cost, and the demand is not only for a suitable structure at a minimum cost, but for a machine of maximum efficiency at minimum cost. To design a bridge or a roof with the minimum of material, and hence at minimum cost, requires an exact knowledge of statics and of the strength of materials, and although the writer has seen, in a building put up within ten years, a member which was supposed to carry a tensile strain, all buckled from compression, blunders of this character are largely things of the past.

The light and strong bridges and roofs that are now built by the combined efforts of the mathematician and the mechanic, in which every pound of metal is placed where it will do the most good, are examples of what we may hope for in all lines of engineering. Similarly, a steam-engine must have a guaranteed efficiency, and the knowledge of the laws of heat has been combined with that of mechanics to produce a marvelously perfect machine. Again, the rapid development of electrical appliances has been due to the fact that practical application followed scientific knowledge. The laboratory was the leader, and not only pointed out the line of progress, but saved many costly blunders.

The rapid development of steel would have been impossible without the chemical and physical laboratories, where the relation between chemical composition and physical quality could be carefully studied. Efficiency tests, made along strictly scientific lines, have for a long time been applied to boilers, engines, water-wheels, dynamos, electric motors, and the like, and all builders who ignore the scientific principles on which these machines are based soon find themselves out of the race.

Undoubtedly many other special machines are built that give high percentages of efficiency, but there is one very large class which is still built to a great extent without scientific consideration of the work that they are called upon to do. I refer to machine tools. While I do not pretend to say that tool builders are not making progress, I have seen within the past three years lathes from well-known makers that were quite unfitted for the work they were intended to perform.

I refer especially to machines for doing heavy work, and have in mind a so-called forge lathe, designed to rough-turn heavy forgings, and built with two very heavy carriages, each to carry two tools, but having such small pulling power that two tools in a heavy cut at the proper speed would tax the belt beyond its limit, making it impossible to use the four tools to advantage. The lathe is well made in other respects, and is used very successfully for finishing. I

cite this example to explain what I mean, and might give others where the relation between feeds, speeds, and pulling power in an otherwise well-designed lathe is not such as to enable it to do as much work as ought to be possible with such a machine.

To make a machine tool which will do a maximum amount of work of a particular kind we must know what relation the feed, speed, and pulling power should bear to one another to produce that maximum. There is a mathematical answer to this question, but the number of independent variables is so large that its solution seems almost impossible. If it is to be solved at all, the solution must be preceded by a knowledge of the laws of cutting metals, about which at present little is generally known.

For instance, who can tell how much we must diminish the feed in taking a given depth of cut if we wish to double the speed and still have the tool last as long as it would have lasted if we had not doubled the speed? Again, suppose a deep cut becomes less on one end of a piece, at what decrease in depth can we increase the speed by, say, 20 per cent., without increased injury to the tool? Are the laws the same for different kinds of cast iron, and for steel, and for different shapes of tool? Again, what pressure per square inch of chip section is needed to remove metal? How does it differ with different kinds of cast iron or steel? I could go on asking questions of this kind almost indefinitely and feel sure that I could get but few definite answers; yet it is necessary to know all of these facts before a machine of maximum efficiency in cutting metals can be built.

Such facts are not easy to get. They are dependent upon so many conditions that to many the task of getting them appears hopeless. Even to devise a method of study is a problem beyond the power or patience of most men, but the writer is able to say that a start has been made, and so successfully that not only is the method of working entirely clear, but many valuable results have already been obtained. In 1880 Mr. Fred W. Taylor began to study the laws of cutting steel, and within the past four years the results of his work have been reduced to a slide rule system by the writer and Mr. Carl G. Barth and put into such shape that a fairly well-educated mechanic can use them successfully.

But little has been done with cast iron, and while the writer does not pretend that all the laws regarding the cutting of steel are known, or that those that have been determined are known with absolute accuracy, he does maintain that enough is known to enable us to get very nearly a maximum amount of work out of a poorly designed tool and to give specifications for building a tool that will be a very efficient steel-cutting machine. The problem of designing a most efficient machine tool is one that especially interests the builder, while that of getting the most out of the tools he has, interests every man connected with a machine shop. It is almost impossible to realise the difference between the amount of work obtainable from a lathe rough-turning steel when run in accordance with the laws that have been determined and when it is run by the judgment simply of an ordinary, or even a first-class, workman. The increase in output is nearly always 100 per cent., frequently 300 per cent., and sometimes 500 per cent.

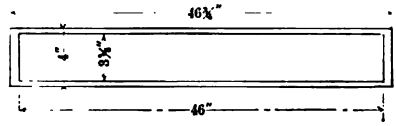
I can now imagine myself attacked by an army of machine shop foremen and not a few managers, who laugh at my utopian ideas and inquire as to the good of all this when they cannot get into the heads of their men the facts already known? Again, of what value is it to a man to know all this if he cannot be made to carry it out? He will not do it on day work, and if you set a piece rate, based on the figures given, you will have a strike at once. Yet the result has been, and is still being, accomplished by the "bonus system of rewarding labour," devised by the writer and first introduced under his direction in the large machine shop of the Bethlehem Steel Company. A full description of this was given by the writer in a paper read before the Ameri-

CLASS OF WORK	STANDING ORDER	ORDER NUMBER
Lathe	*376*	*17344*
MACHINE NO. TOOL	**CLASS OF METAL**	**FORGING NUMBER**
145 M E H	*12*	*14653c 4*

MAN'S NAME *Wm. Jones* SPEED BOSS *Thos. Smith*

	DESCRIPTION OF OPERATION	SHAPE OF TOOL	CUT	FEED	SPEED	TIME WORK SHOULD TAKE	TIME WORK DID TAKE	RATE
1	*Chuck*					*2.5*		
2	*Face end*	*P V M*			*2 B F*	*4 0*		
3	*Turn half way*	*P R L*	$\frac{3}{16}$	*J*	"	*12.0*		
4	" *end for end*					*5.0*		
5	" *half way*	*P R L*	$\frac{3}{16}$	*J*	"	*12.0*		
6	*Face end*	*P V M*			"	*4.0*		
7	*Remove from machine*					*2.5*		
8						*42.0*		
9								
10								

Inside lines in sketch represent machined, and outside lines forged, sizes.



NOTE.—Sketches are not usually put on the instruction cards, but are put on here for convenience.

INSTRUCTION CARD NO.	SHEET DRAWING NO.	B. S. Co. DRAWING NO.	MONTH	DAY	YEAR	SIGNED
4327		*26627¼c*	*6*	*1*	*1901*	*Buckley*

WHEN MACHINE CAN NOT BE RUN AS ORDERED, SPEED BOSS MUST AT ONCE REPORT TO MAN WHO SIGNED THIS SLIP.

FIG. 1

can Society of Mechanical Engineers in December, 1901.

The substance of the system is that men working at day's wages receive, in addition to their regular wages, a substantial bonus for doing work in the manner and time prescribed. They receive full, detailed instructions as to how to perform each of the elementary operations on a piece of work with the time each should take, and as these instructions and times are made out from data known to be correct, the men soon see that they are asked to do only what is reasonable, and accordingly make efforts to earn the bonus. Such efforts are not always crowned with success at once, but the instructions are intended to be so definite that a man of very ordinary intelligence can learn to carry them out, and, with reasonable industry, can do the work in the time set. In order to make clear the subject of the instruction cards which are used, it is, perhaps, best that I quote a description of them from my paper above mentioned:—

The work to be done on a machine, say a lathe, is analysed by a first-class machinist who has been instructed in the use of the slide rule, and who makes out a card on which the operations to be performed on this lathe are placed in the proper order, with proper instructions, the calculated time that is necessary for performing each operation being given. The kind of tool to be used, the feed, and the speed are specified for every machine operation. For every other operation, such as putting in and taking out work, laying out, changing feed gears etc., instructions are given when necessary, and the time that each should take is placed directly opposite the instruction, in a column designed for that purpose. Fig. 1 shows a sample card for rough-turning a locomotive piston rod.

This card represents instructions given to William Jones, whose boss is Thomas Smith, to do work on Forging No. 14,653*C*4, Manufacturing Order No. 17,344, in Lathe No. 145, according to Standing Order No. 376. The hardness of the metal is represented by Class 12. He must use tools made of "*M. E.*" steel, of the shape designated in the column calling for shape of tool. The approximate depth of cut in turning is 3-16 inch; "*J*" represents a combination of feed gears, and "2-*BF*" a cone-speed which he must use. Opposite each operation are seen complete instructions, giving the kind of tool, cut, feed, and speed that must be used in order to accomplish the work in the time set. The total time for turning and facing this forging is shown to be forty-two minutes.

At the bottom of this card are given, first its number, then the drawing number of the assembling sheet, if we have such a sheet; then the detail drawing for this particular piece, and next the date and signature of the man who made out the card. The note at the bottom, namely, "When machine cannot be run as ordered, Speed Boss must at once report to the man who signed this slip," is put on in red ink, and should be observed to the letter.

By means of a card filled out from the slide rule, together with records of the time necessary to perform the miscellaneous operations, which for simplicity we shall call "hand work," a very ordinary man can be instructed in the best method of doing a piece of work. Considerable training, of course, is necessary to teach the men to follow these cards, but having once given them this training, the advantage of having a first-class machinist to do the thinking, and to use for them the best results already obtained, produces an efficiency which would be impossible if the workmen were left to themselves.

For further illustration I give, in Fig. 2, a somewhat longer card for turning portions of a crankshaft, and wish to call attention to the fact that similar cards, more than twice as long as this one, have been used with entire satisfaction. Figs. 3 and 4 are two shorter cards, given to show the difference between the ordinary day-work time and that needed with instruction cards and a bonus.

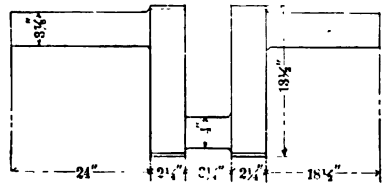
I now fancy the readers who have had the patience to follow me so far asking

CLASS OF WORK	STANDING ORDER	ORDER NUMBER
Lathe	*460*	*16837*

MACHINE NO.	TOOL	CLASS OF METAL	FORGING NUMBER
59	M E	*14*	*22706 B 1 F 1*

MAN'S NAME ..... SPEED BOSS .....

	DESCRIPTION OF OPERATION	SHAPE OF TOOL	CUT	FEED	SPEED	TIME WORK SHOULD TAKE	TIME WORK DID TAKE	RATE
	Change machine 20 minutes (for 1st one only)							
1	*Chuck for turning webs*					*12*		
2	*Turn webs*	*P R L*	*3 cuts*	*E*	*4 A F*	*1:40*		
3	*Change to Pin Centres*					*10*		
4	*Rough Pin to 4 1/16 dia.*	*P S R*		*0.005*	*5 A F*	*2:10*		
5	*R face webs use double end tool*		*2 cuts*		*4 A F*	*1:40*		
6	*Finish " " " " "*		*1 cut*	*H*	*"*	*50*		
7	*Finish turning pin & cut fillets*			*E*	*2 A F*	*2:00*		
8	*File pin round*					*1:10*		
9	*Polish pin*				*2 B F*	*40*		
10	*Inspect*					*15*		
11	*Remove crank*					*05*	*hr.min.*	
12						*10:52*	*10:50*	
13	*Pin is No. 1 finish ; webs are No. 3 finish*							
14								
15	*(Bonus earned)*							



Previous time 54 hours

INSTRUCTION CARD NO.	SHEET DRAWING NO.	B. S. CO. DRAWING NO.	MONTH	DAY	YEAR	SIGNED
4811	*F M C B*	*261941 A*	*7*	*17*	*01*	*Buckley*

WHEN MACHINE CAN NOT BE RUN AS ORDERED, SPEED BOSS MUST AT ONCE REPORT TO MAN WHO SIGNED THIS SLIP.

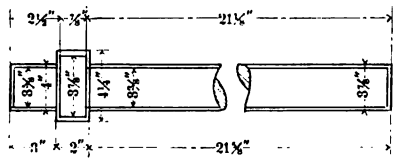
FIG. 2

CLASS OF WORK	STANDING ORDER	ORDER NUMBER
Lathe	*570*	*17351*

MACHINE NO.	TOOL	CLASS OF METAL	FORGING NUMBER
160	M E	*15*	*18253 B 1 F 1*

MAN'S NAME..... SPEED BOSS.....

	DESCRIPTION OF OPERATION	SHAPE OF TOOL	CUT	FEED	SPEED	TIME WORK SHOULD TAKE	TIME WORK DID TAKE	RATE
	Change machine 5 minutes (for 1st one only)							
1	*Chuck 3⅜" to F P*					*2½*		
2	*Turn 3⅜" × 21⅛" long*	*P R L*	*¼*	*i*	*2 B F*	*11*		
3	*Face end*	*P V M*			"	*05*		
4	*Turn end for end*					*04*		
5	*Face end*	"			"	*05*		
6	*Turn 3⅛" Dia.*	*P R L*	*¼*	"	"	*02*		
7	*Turn 3⅜"* "	"	*¼*	"	"	*03*		
8	*Remove piece*					*2½*		
9						*35*	*34 min.*	
10								
11								
12		*(Bonus earned)*						
13								
14								
15								
16								
17								
18								
19								
20	*Previous time taken 1 hr. 6 min.*							
21								
22								
23								



INSTRUCTION CARD NO.	SHEET DRAWING NO.	B. S. CO. DRAWING NO.	MONTH	DAY	YEAR	SIGNED
5368		*6258*	*9*	*12*	*01*	*Buckley*

WHEN MACHINE CAN NOT BE RUN AS ORDERED, SPEED BOSS MUST AT ONCE REPORT TO MAN WHO SIGNED THIS SLIP.

FIG. 3

CLASS OF WORK	STANDING ORDER	ORDER NUMBER
Lathe	*580*	*17058*

MACHINE NO.	TOOL	CLASS OF METAL	FORGING NUMBER
76	M E H	*16*	*22834 B 1 F 2*

MAN'S NAME..... SPEED BOSS.....

	DESCRIPTION OF OPERATION	SHAPE OF TOOL	CUT	FEED	SPEED	TIME WORK SHOULD TAKE	TIME WORK DID TAKE	RATE
	Change machine 10 minutes (for 1st one only)							
1	*Chuck*					*04*		
2	*Turn half way*	*P R L*	*⅛"*	*E*	*3 A F*	*30*		
3	*Face end*	*P V M*			*"*	*17*		
4	*Turn end for end*					*06*		
5	*Face end*	*"*			*"*	*17*		
6	*Turn half way*	*P R L*	*"*	*"*	*"*	*30*		
7	*Remove piece*					*03*	*hr. min.*	
8						*1:47*	*1:50*	
9								
10	*(Bonus not earned)*							
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21	*Previous time on another lathe 5 ½ hrs.*							
22								
23								

INSTRUCTION CARD NO.	SHEET DRAWING NO.	B. S. CO. DRAWING NO.	MONTH	DAY	YEAR	SIGNED
5613	*F C A C*	*25330½ C*	*9*	*18*	*01*	*Buckley*

WHEN MACHINE CAN NOT BE RUN AS ORDERED, SPEED BOSS MUST AT ONCE REPORT TO MAN WHO SIGNED THIS SLIP.

FIG. 4

if all this pays, and my answer is to look at the results, for the last three cards give the time taken in actual cases to do the work both before and after the introduction of the instruction cards and the bonus system.

	Time Needed.	
Card No.	Before.	After.
4811	54 hrs.	10 hrs. 50. min.
5613	5 hrs. 30 min.	1 hr. 50 min.
5368	1 hr. 6 min.	34 min.

The total time for the three jobs before the introduction of the system was 60 hours and 36 minutes, or 3636 minutes. The total time needed after the introduction of the system was 13 hours and 13 minutes, or 793 minutes, which is 22 per cent of the former time. In other words, the output of the lathe was increased nearly 400 per cent. While the cards here chosen are good ones, they are by no means exceptional; neither is the time for doing the work previous to the introduction of the system exceptionally long. Indeed, from what I have been able to see in many shops it was fully as short as the average for the same work. This possible gain settles in the mind of the writer the advisability of doing work this way, and we now come to the question of how to get the information needed to make out such instruction cards.

Each operation has to be studied by itself, not only to find the best time in which it can be done, but to determine the best method, and the time necessary to perform the elementary operations of which it is composed. In other words, each must be subdivided into its elements and each element made the subject of a scientific investigation. This would seem an interminable task, and it is indeed a long one; but when once the work is begun, the information accumulates with considerable rapidity, and, if properly catalogued and systematised, soon becomes valuable. For a fuller description of this study of the elements into which an operation may be divided, I refer to a paper by Mr. Fred W. Taylor on "A Piece Rate System," published in this magazine for October, 1895.

Here, again, those who have had the patience to follow me thus far and to look up the references I have cited will probably agree with me as to the advantages to be secured from this method of working, but will feel that it is not applicable to their particular shop. This is undoubtedly so, unless great changes are made in the method of managing; but it is just the condition of affairs that the instruction cards and the bonus system are devised to meet.

A careful consideration of the writer's paper previously referred to will show that while the method described of getting information is the ideal one, and to be approximated as nearly as possible, there is no reason why such information as is at hand should not be made use of at once by means of instruction cards, which latter afford the best available means of recording our knowledge of how to do work.

In every shop there is some man who knows more about the work than the others, and a start may be made by having him make out such cards as he can. A bright man, capable of careful observation, will soon improve his cards, and in a short time a start will have been made sufficient to show the desirability of modifying the shop management to such an extent that the system can be developed to a higher state of efficiency.

The instruction card system is the only means of which the writer knows by which anything like the full efficiency of the recent advance in tool steel can be taken advantage of, for men accustomed for years to one grade of tool steel cannot bring themselves up to the point of driving their machines three or four times as fast as has been their custom. When, however, the responsibility for the effect of the high speed is assumed by someone else and a bonus is offered for the result, the most stolid workman will gradually fall into line and reach for the bonus held out to him.

This brings us to the educational point of view, for while the workman is acquiring his increased efficiency, he is also receiving increased wages, and, if I have satisfactorily shown that it is to the interest of the employer to give the

increased wages, it would seem that we have the basis of a system that works for the interests of both employer and employee. In other words, experience in the lines described has shown that the results of the scientific method are such that if an employer can have this method carried out, he can not only pay for his experiments, but give his workman a liberal bonus for learning and doing what he has found out by his investigations. It would seem that such a system would have a tendency to produce harmony between employers and employees for their mutual benefit, and so far this has been found to be the case.

I have been asked what effect an improved tool steel has on the output of a shop, and have answered without hesitation that neither a new tool steel nor a new machine tool had any very appreciable effect unless steps were first taken to find out definitely what the new tool steel or tool would do and then a system of management was adopted that taught the workmen how to get out the maximum product, and made it to his interest to do so. This example seems to the writer a good summary of his paper, which may be further condensed into three heads, as follow:—

To learn,
To teach,
To reward performance.

If there be a science of management, and the writer believes that there is one, it certainly contains these three divisions as integral parts.

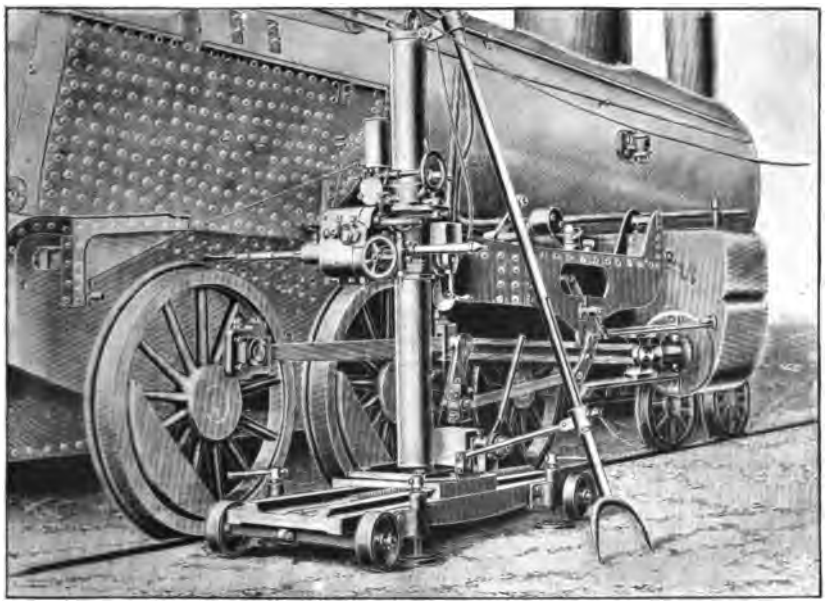
Further, these are general divisions, and applicable not alone to the machine shop, but to the forge and foundry, and, indeed, to any work performed by men and methods.

It is proper to add, however, that the introduction of any system of this type presupposes a time and record-keeping system by means of which exactly what every man and machine have done during working hours can be known. Of the various time-keeping systems the only one adapted to doing this in a satisfactory manner is the time card system, which, in its best development, not only gives the most accurate returns of time and labour, but does it with less clerical work than is usually expended on inferior systems.

The value of the time card is being gradually recognised, but few managers realise what a powerful economising influence it may become if all its possibilities are utilised.

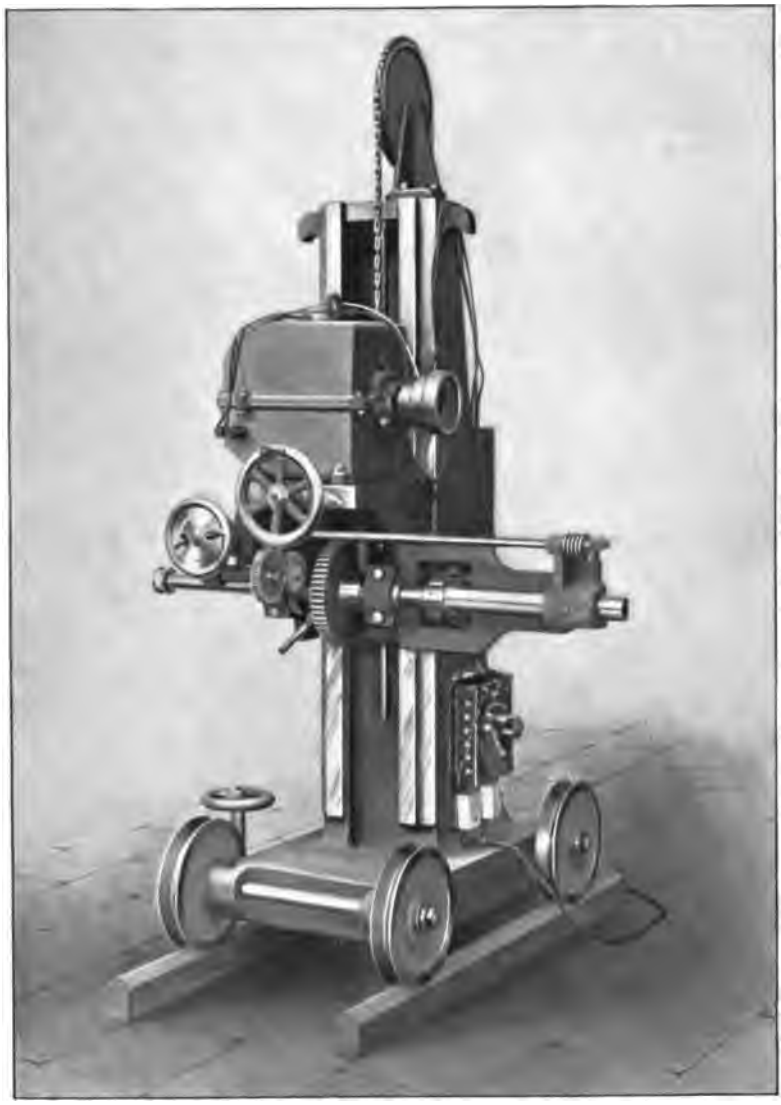
PORTABLE MACHINE TOOLS

By Forrest R. Jones



A PORTABLE STAY-BOLT DRILLING MACHINE. MADE BY MESSRS. HABERANG & ZINZEN, DUSSELDORF-OBERBILK, GERMANY

IN the earlier processes of machine construction, when the parts to be accurately finished were small, the removal of stock with cutting tools to produce the required accuracy of finish was almost universally accomplished by stationary machine tools The lathe, the planer, the shaper, and the drill-press were permanently located, in many cases upon masonry foundations built expressly to fit a particular machine tool. The parts to be machined were brought to the operating machines and adjusted to positions suitable for the tool to perform its operations upon them. This very frequently made it necessary to set a piece of work several times upon the same tool, once for each operation. As the machines undergoing construction increased in size and weight, the difficulty and expense of repeated settings increased. This led to the introduction of machine tools which could perform several operations upon a piece once set without moving it. For large parts requiring several operations by the same machine tool, the drill-press, with its vertical spindle stationary except in its rotation and feed stroke, and its movable table, was replaced and improved upon by the radial-arm drill-press with its swiveled spindle-head, the latter adjustable radially along the arm. Vertical drilling could be done by this tool anywhere within the effective radius of the spindle, and, by means of the swiveled spindle-head, drilling could be done horizontally as well as vertically, and at any angle with the vertical. The horizontal-



A PORTABLE HORIZONTAL DRILLING AND BORING MACHINE, DESIGNED FOR DRILLING LOCOMOTIVE FRAMES. BUILT BY MESSRS. WM. MUIR & CO., LTD., MANCHESTER, ENGLAND

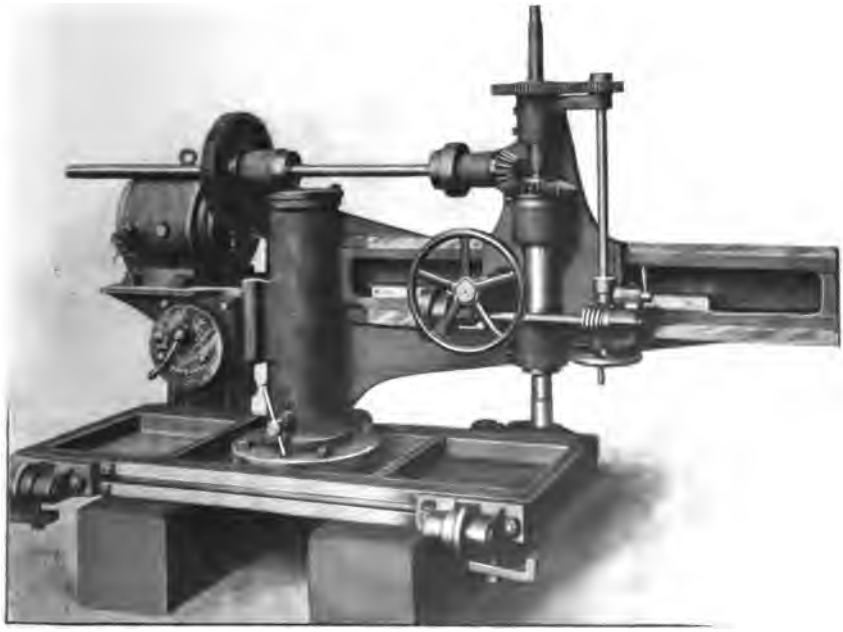
spindle drilling and boring machine, with a spindle axis always remaining in the same position and a table adjustable both vertically and horizontally, answered well for all work that could be supported by the table. But when the pieces became too heavy for the machine to support them alone, and had to rest partly or wholly upon blocks or other supports, the difficulty and cost of resetting for each operation were excessive. In order to facilitate the execution of this class of work, a horizontal-spindle drilling, boring, and milling machine has come into use, in the early form of which the horizontal spindle was supported by a head which moved vertically upon a firm column or housing. This housing, in turn, moved horizon-

tally on a bed in a direction perpendicular to the length of the spindle. By this means the spindle could be brought in position to drill, bore, or mill anywhere over the rectangular area of a flat surface standing vertically in front of the spindle and at right angles to it. A single setting of the part under construction answered for all the operations within the range of travel of the spindle. This machine is the prototype of many, excellent in both design and construction, that have since been built.

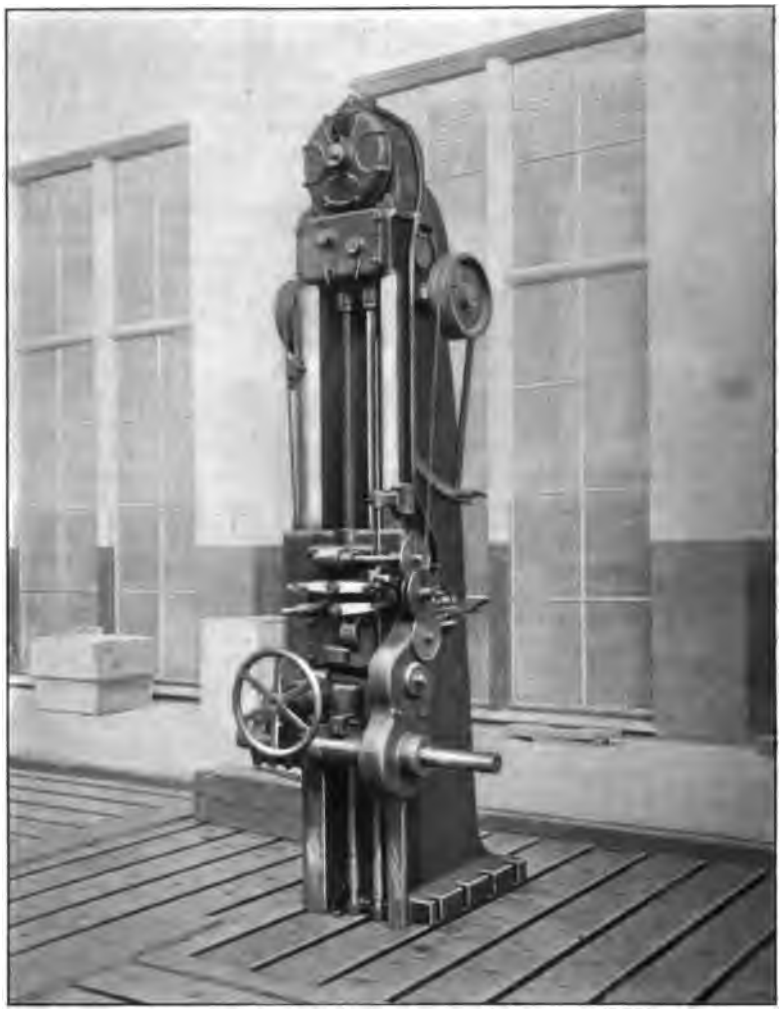
The lathe and planer have not changed materially in the principles of operation since their first appearance. The shaper has followed somewhat in the path of the drilling and boring machines, by a change from a stationary head forming a rigid portion of the frame, to a traveling head for carrying the reciprocating ram.

But as machinery increased still more in size and weight, even the changes just mentioned did not suffice for rapidity and economy of production. It became easier, in many cases, to carry the operating tool to the piece to be operated upon than to follow the old plan with stationary tools. Portable machine tools were thus brought into operation and are now found in the plants of many of the leading builders of heavy machinery. A description of some of the uses to which such tools are put will show in a measure to what extent they are used. The examples selected are typical.

In the case of some blowing engines built at a certain works, very large cylinders with steamchests bolted on are made. For drilling and tapping the bolt holes for attaching the steamchest, the cylinder is laid on its side with the planed surface, against which the chest fits, at the top. A portable radial drilling machine with a plane machined surface at the bottom is placed on top of the steamchest seat so that it can drill some of the holes. The drill is then shifted and the remainder of the holes completed. Power is furnished by a variable speed electric motor, at-

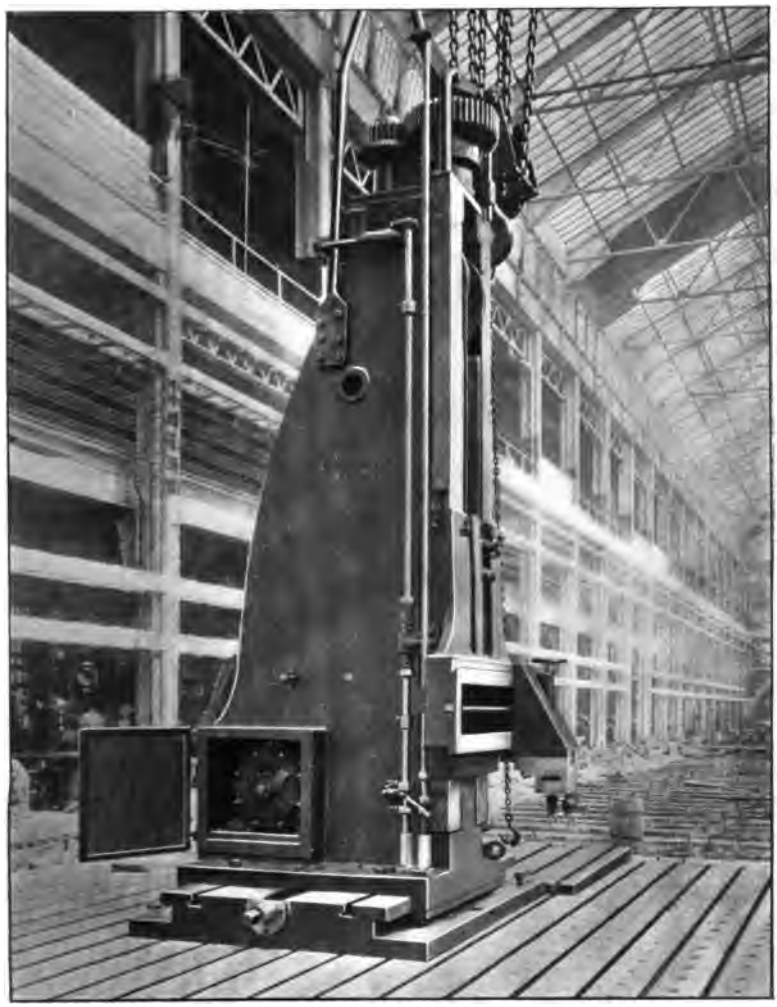


A PORTABLE RADIAL DRILLING MACHINE WITH 4-FOOT RADIUS FOR BRIDGE WORK, BEING BUILT TO TRAVEL ALONG GIRDERS OF VARIOUS WIDTHS FOR DRILLING HOLES WITHIN RANGE AND THEN MOVING ON FOR ANOTHER SETTING. BUILT BY WM. ASQUITH, HALIFAX, ENGLAND



AN ELECTRICALLY DRIVEN PORTABLE VERTICAL MILLING MACHINE IN THE SHOPS OF THE WESTINGHOUSE ELECTRIC AND MANUFACTURING CO., PITTSBURGH. THE TOOL IS BOLTED TO THE MACHINED FLOOR-PLATE, WHICH IS PROVIDED WITH "T" SLOTS FOR THIS PURPOSE

tached to and forming part of the machine. It is obvious that the work can be done wherever it is convenient to place the cylinder, provided the plant is properly wired for furnishing electric energy. When placed upon a suitable bedplate and furnished with the other accessories common to stationary drills, this portable drill becomes the equivalent of a stationary one, and is, therefore, doubly useful. Such a bedplate is used by the company in question. In the engines of the same establishment the ports of the air valves for the blowing cylinders are narrow radial slots in a circular cylinder head. The sides of these slots are machined by a special portable planer which is attached to the valve. The stroke of the cutting tool is radial with the valve. The frame of a horizontal engine is machined to receive the box of the main bearing by a portable draw cut planer or slotter which is attached direct to the engine frame. The tool is entirely self-contained. It is driven by its own electric motor.

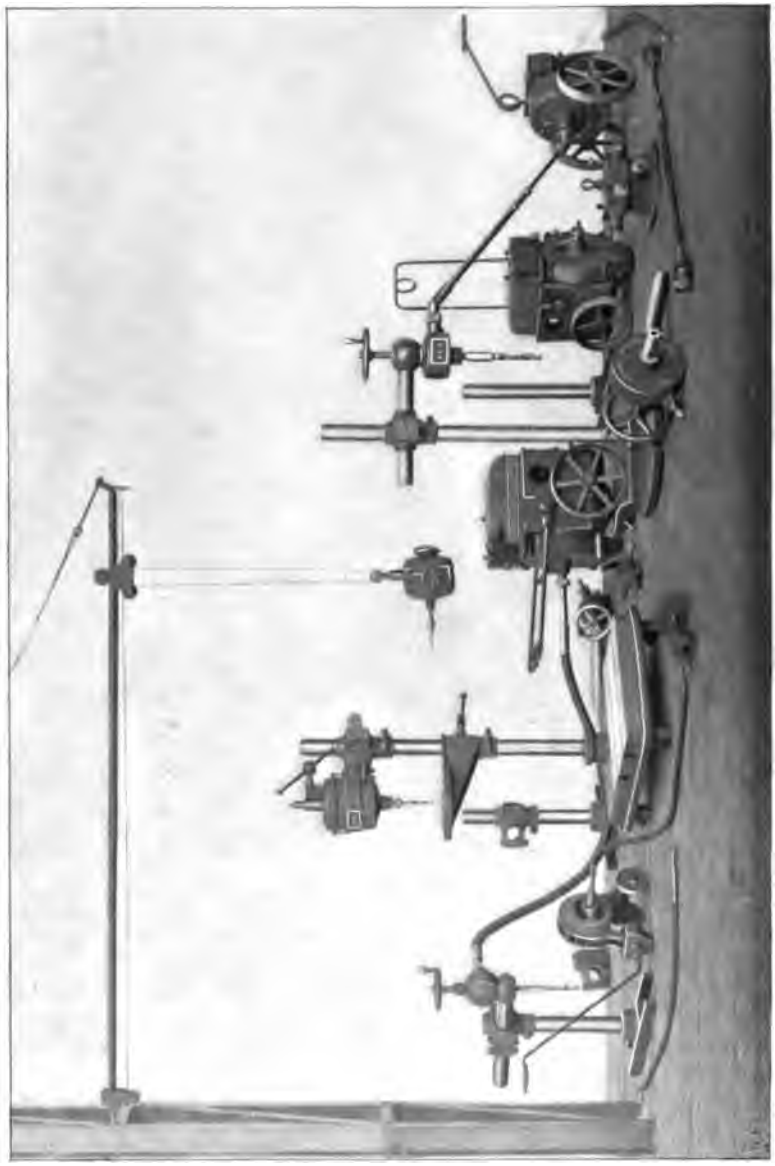


A VERTICAL PORTABLE PLANER OR SLOTTER. BUILT BY THE NEWTON MACHINE TOOL WORKS, OF PHILADELPHIA. THE WESTINGHOUSE INDUCTION MOTOR DRIVING THIS TOOL IS INSIDE THE HOLLOW COLUMN OF THE MACHINE

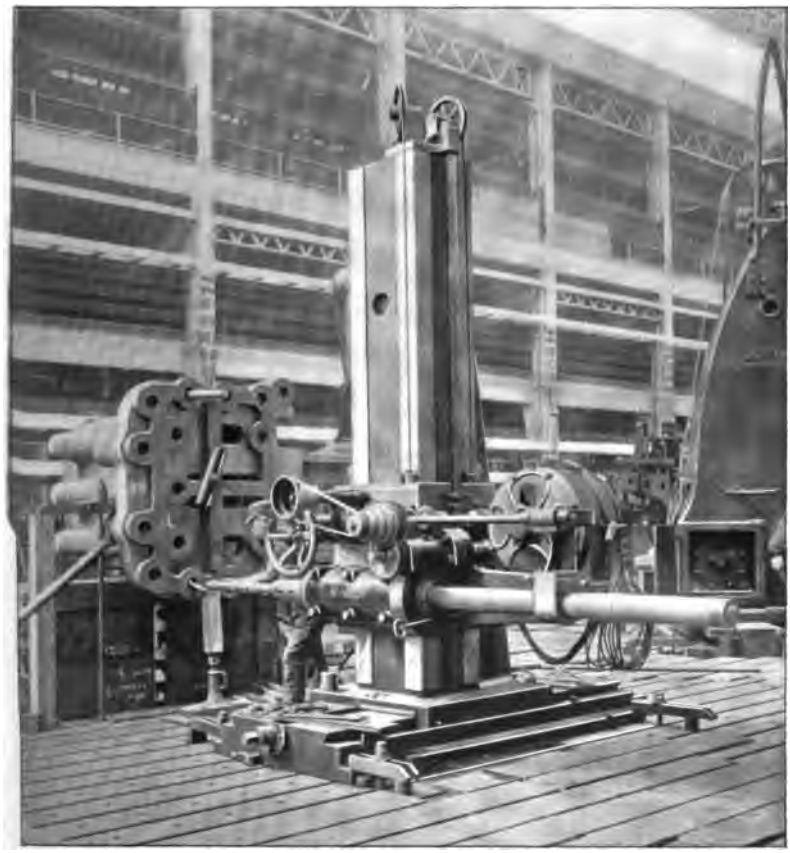
One of the large engine-building companies also use a portable draw-cut shaper for planing out the main bearing space on their heavy-duty engines. In their segmental flywheels the holes, parallel to the axis of the wheel, for the bolts that fasten the arms into the hub, are drilled by a portable radial drill mounted on a mandrel that fits into the bore of the hub. This machine is driven by a six horse-power vertical spindle electric motor, and will drill as large as 4½ inches diameter.

Another firm uses a portable boring machine for boring out the seat for the main bearing boxes of their engines. It is set on top of, and bolted to, the frame during the operation. Part of the bore is spherical, and part cylindrical Both parts are bored by tools cutting at the same time.

At the Pittsburgh works of the Westinghouse Electric and Manufacturing Company, the recent construction of some huge electric railway generators involved the use of several types of



A MISCELLANEOUS LOT OF PORTABLE, ELECTRICALLY DRIVEN TOOLS MADE BY THE ALLGEMEINE ELEKTRICITAETS GESELLSCHAFT, BERLIN, GERMANY

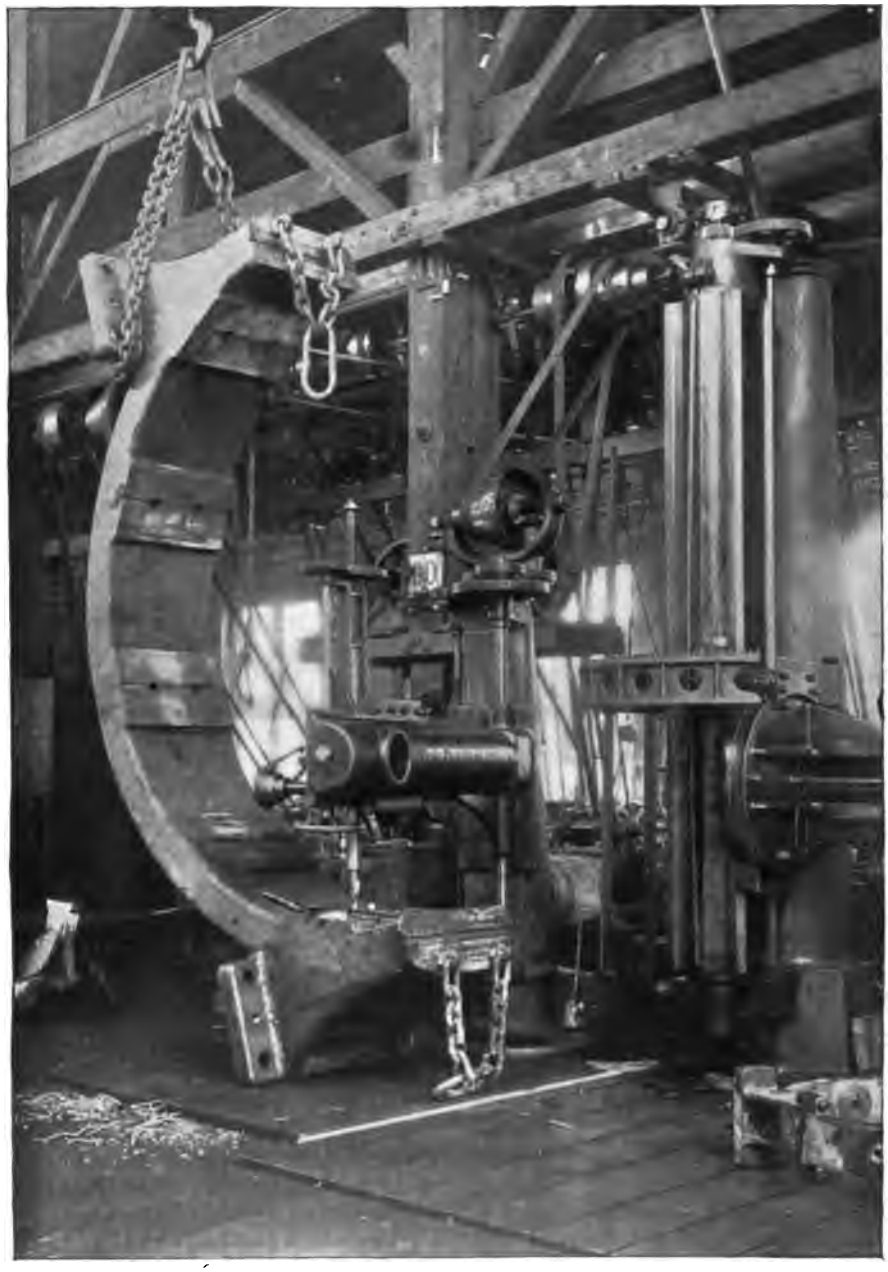


A PORTABLE DRILLING MACHINE BUILT BY THE NEWTON MACHINE TOOL WORKS, OF PHILADELPHIA. DRIVEN BY A WESTINGHOUSE INDUCTION MOTOR

portable tools. The keyway in the hub of the rotary field is cut by a draw-cut, motor-driven slotter placed on top of the hub as it lies on the floor with the axis of its bore vertical.

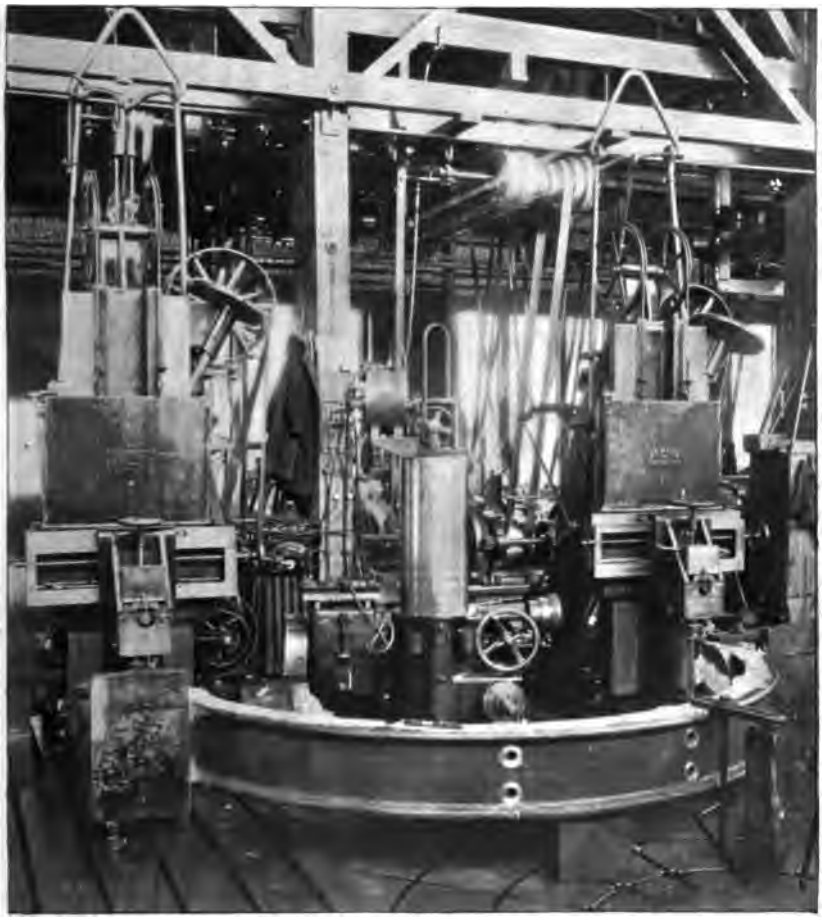
The machine operations on the sections of the frame of the generator required portable tools and a floor-plate. The plate in use has a horizontal, machined surface 176 × 48 feet. It is made up of sections 8 feet square and 15 inches deep. These sections are machined on the edges and fastened together. Keys are used at the corners of each section to hold it in place. There are numerous slots for bolts in the top.

The method of setting the tools in position is novel and worthy of description. First, the frame section is placed on its side and leveled on the floor-plate in a position selected by judgment as suitable. A metal stand for a surveyor's transit is then located by trial at the centre of the inner arc of curvature of the segment. The radius of curvature is about 16 feet. A transit is placed on this stand and used to set a pair of straight edges, one under each end of the segment, on the floor-plate, and at an angle with each other corresponding to that which the segment is to occupy in the entire frame. A portable slotter is then placed at each end of the segment in a position to plane the ends so that the machined surface will be immediately over its own straight-edge. The slotters are set in



THE OLD WAY OF DRILLING A CASTING IN THE SHOPS OF THE GENERAL ELECTRIC CO., AT SCHENECTADY, N.Y. THE NEW WAY WITH THE SAME CASTING IS SHOWN ON THE OPPOSITE PAGE

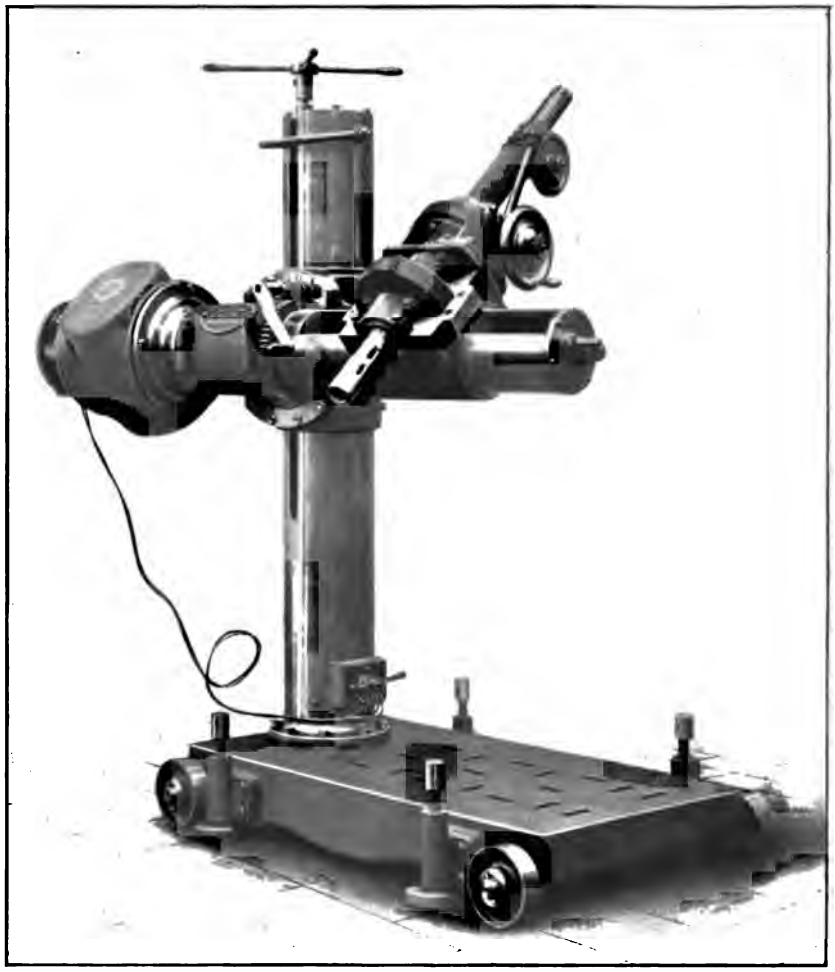
position by reference to the straight-edges. Each slotter is self-contained. It is driven by an electric motor placed inside the hollow column, or housing, as shown on page 131. The transit is also used to lay off centre-lines on the inner curve of the segment to which the milling and slotting machines can be set



TWO PORTABLE SLOTTING MACHINES AND A PORTABLE DRILLING MACHINE, ALL ELECTRICALLY DRIVEN, ARE HERE SHOWN AT WORK ON THE CASTING

for operating on that part of the casting. The rotary field of each of the above mentioned generators is also placed on the floor plate and machined with portable tools. The field, about 30 feet in diameter before the pole pieces are attached, is placed on its side on the floor-plate. It is partly supported at the centre by a single ball fitting into suitable sockets, one resting on the floor-plate and the other attached to the hub of the field. The remainder of the weight is carried by supports placed under the edge near the periphery. Three portable tools, a milling machine, a slotter, and a radial drill, are placed near together for operating simultaneously upon the field piece. After once setting the tools they are not again moved, but the field is turned on the ball at the centre to bring all parts near the edge within reach of the machines.

The General Electric Company has in its large shops at Schenectady, New



A 6-FOOT RADIAL DRILLING MACHINE WITH 3-INCH SPINDLE. BUILT BY THE ATLAS ENGINEERING CO., MANCHESTER, ENGLAND

York, a floor-plate 125 × 30 feet, and a very complete equipment of portable tools.

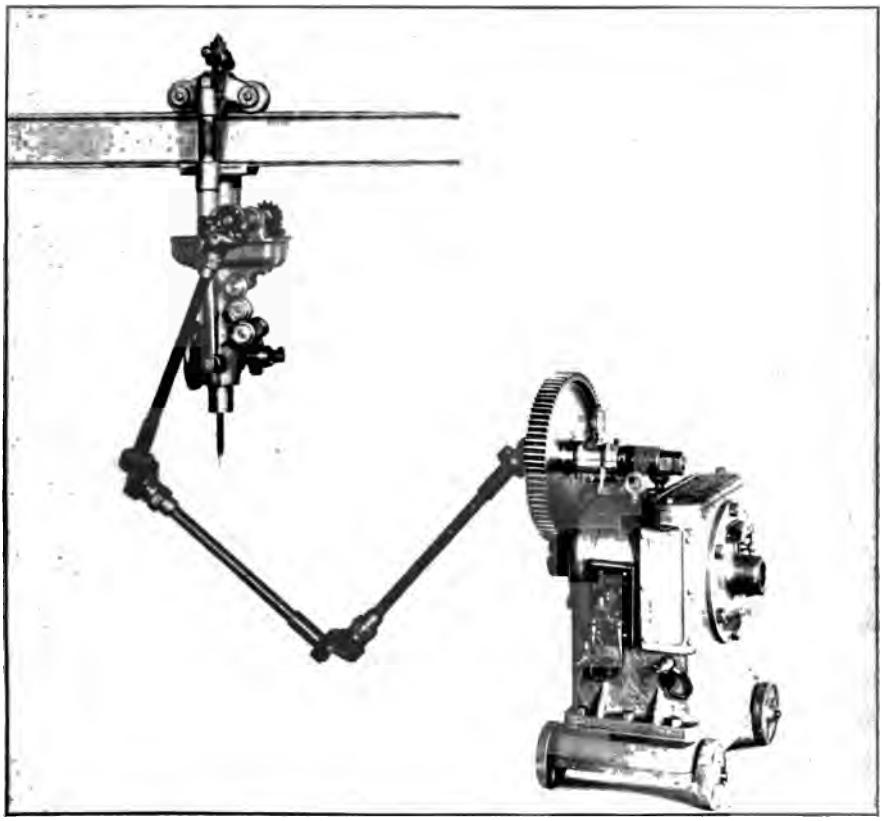
The United States Navy Yard, at Brooklyn, has some portable machine tools in its shop equipment, the most notable ones being a portable shaper with milling attachment, and a portable slotting and keyseating machine. The chief features of these machines may be of interest. The horizontal ram of the shaper has a stroke adjustable in length and position, as is common to shapers, with a maximum of 4 feet. The feed has a range of 6 feet horizontally and 4 feet vertically. The ram is a square, hollow, steel casting through which a spindle for the milling attachment passes from end to end. The milling cutter is attached, when in operation, to this spindle at the head end of the ram. There is the same range of feed for milling as for shaping. The power is furnished by a 7½ horse-power alternating current motor. Two milling speeds are provided for by the use of a pair of two-step pulleys. The reciprocating motion of the ram for shaping is at one speed only. The machine is used either by attaching it directly

to the piece it operates upon, or by placing both the machine and the work on a floor-plate. This particular machine has a floor-plate 9 × 10½ feet. It is of ribbed construction, about 1 foot deep.

The keyseating and slotting machine is powerful enough to cut a keyway 2 inches wide by 48 inches long with a single setting of the cutting tool. The feed is radial to the bore of the piece in which the keyway is cut. The machine is driven by an individual electric motor of the alternating current type.

One large American shipbuilding plant has in operation several portable machines of a somewhat different nature than those ordinarily designated as machine tools. They are of such great improvement over what has heretofore been used for the same purpose, as to well deserve mention. One of these machines is a punching press for operating on flat hull-plates. The frame is of the usual open C-frame type. Instead of the usual foundation there is a car that runs upon a two rail track. Upon this car is a truck that rests on rails placed at right angles with those under car. The punch frame rests upon the truck. The ground tracks are sunk in a pit of a depth suitable for the operation of the punch upon horizontal plates at a height common for press work. Hydraulic power is used for both adjusting the machine in position and for forcing the punch through the plate.

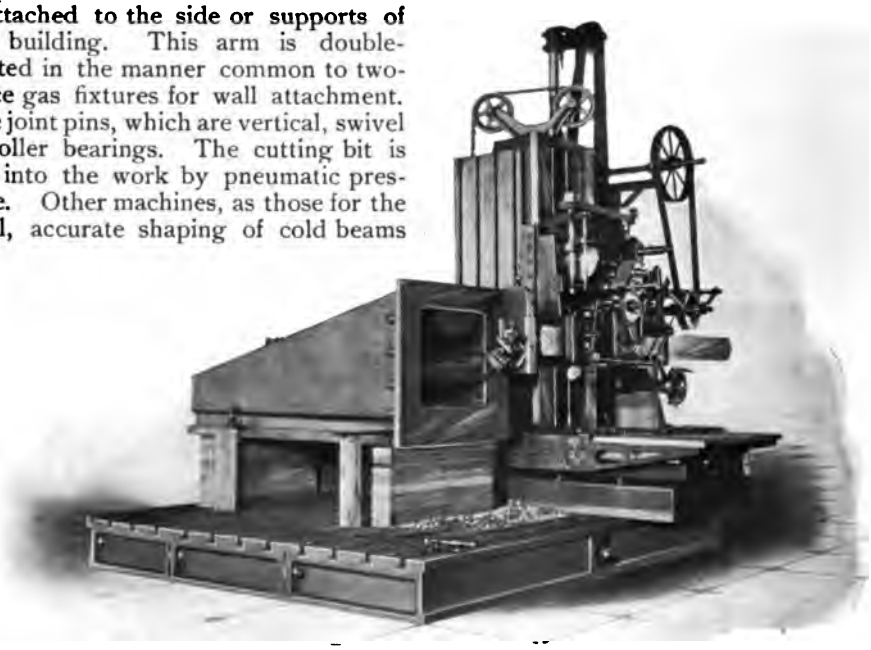
The operator stands on the truck and controls the machine by two levers and



A PORTABLE ELECTRIC MOTOR DRIVING A DRILL FOR BEAMS AND OTHER SIMILAR WORK. THE DRILL IS CARRIED ALONG BY AN OVERHEAD TROLLEY ARRANGEMENT AS SHOWN. MADE BY MESSRS. ERNEST SCOTT & MOUNTAIN, LTD., NEWCASTLE-ON-TYNE, ENGLAND

a pushbutton, the latter in the end of one of the levers. One lever adjusts the punch along the length of the plate, and the other across the plate. By closing an electric circuit with the pushbutton, an electric controller which operates the hydraulic valves for admitting liquid to force the punch through the plate is set into action. This controller operates the valves so that the punch, once started, passes through its complete cycle and then comes to rest. The machine is operated by a boy.

After punching, the holes are countersunk by motor-driven machines, each supported at the end of an arm which is attached to the side or supports of the building. This arm is double-jointed in the manner common to two-piece gas fixtures for wall attachment. The joint pins, which are vertical, swivel in roller bearings. The cutting bit is fed into the work by pneumatic pressure. Other machines, as those for the final, accurate shaping of cold beams and channels that have first been brought approximately to form while hot, are supported and operated in a similar manner.

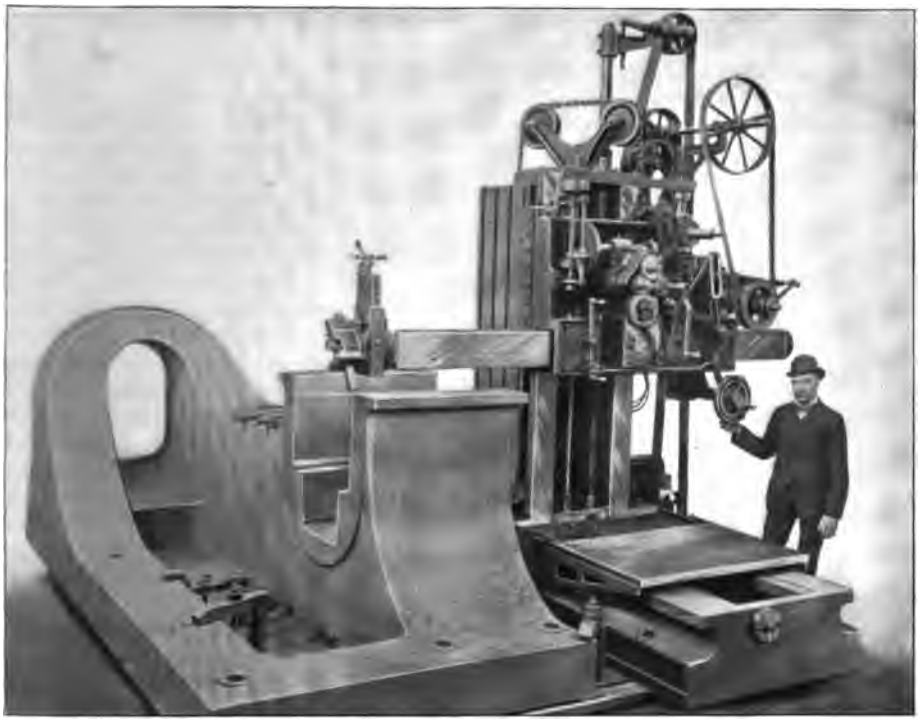


A PORTABLE PLANER MADE BY MORTON MANUFACTURING CO., MUSKEGON HEIGHTS, MICH., U. S. A., MACHINING THE BOTTOM OF A COLUMN

Many other concerns are using, or planning to use, portable tools of the general nature of those here mentioned. One prominent establishment is said to be arranging to perform twelve different operations upon its engines with portable tools electrically driven by direct current.

There is a host of smaller tools, such as pneumatic and hydraulic punches, riveters, hammers and bending machines; also drills driven by portable electric motors mounted on wheels and entirely self-contained, that are of somewhat different nature from the ones thus far considered. These are increasing rapidly in their application, size, and importance. The speed control of portable machine tools is as important a feature as for those that are stationary. It seems to have been much neglected in many cases, but is now receiving more attention.

Following the old tradition that the producer of a ware is the last to use it, the builders of machine tools seem to be the slowest about putting them to their own use, although there are many places where they would effect a great saving in time and cost, especially in



MACHINING A MAIN BEARING SPACE IN AN ENGINE BED WITH A PORTABLE MORTON PLANER

the heavier construction. The machining of small areas on large castings, difficult of access to large tools, planing across the ends of long pieces, drilling and tapping holes for such purposes as attaching racks, gears, and spindles to the tables of heavy boring and turning mills and planers, can be done at any convenient place with a portable tool. Frequently such a tool will require no attention other than that of the operator from the time it is set down by the crane until the work to which it is applied is completed.

FACTORY DEPRECIATION

THE PROBLEM OF CORRECT VALUATION

By Ewing Matheson, M. Inst. C. E.

THE increased attention given during recent years to improved methods of factory administration has been largely stimulated by American example. The laying out of works so as to allow the most economical sequence of operations, the standardisation of patterns, and the consequent facilities for repetition-tools are all regarded now with much greater interest than formerly. Out of this has come the simplification of accounts, not only of material and labour, but also those relating to the distribution of stores. All these, together with the general charges pertaining to the business, afford a basis for estimating future expenditure and profit. But the allowance to be made for that wasting of the capital invested in the factory, due not only to specific wear and tear of the plant, but to many other causes as well, has not received all the attention it deserves.

No concern can last unless the cost of manufacture, which forms the basis of price, is charged with the wear and tear of the apparatus or machinery employed and includes also a provision for contingencies. Such a provision may, like premiums of fire and life insurance, press lightly if attended to from the first. In fire insurance the risk may never become a loss. In life insurance the loss, though long deferred, must come eventually, and so factory plant must, at some time, cease to have any value worth keeping.

There are many differences of detail in the methods of depreciation allowance adopted by managers and accountants. In some cases buildings, machinery, and plant in the factory are treated as a whole; in others these three are classed separately, with a special rate of depreciation for each. A fixed proportion of original outlay may be written off yearly, or a percentage may be deducted on a continually diminishing value. The choice between reserve sinking fund and depreciation is greatly assisted by special tables drawn up for the purpose, showing the different effects of the various systems and the annual charges necessary to each.

It is impossible here to enter into these and other methods adopted by auditors or skilled accountants in applying systems of depreciation, but it is possible, and may be useful, to enunciate the principles involved. If the main point be observed of allowing out of gross income for the contingency of decreasing assets, it is not of vital importance whether such allowance be carried out under the name of reserve, or sinking fund, or depreciation. If thrift be exercised, one need not consider too closely the name given to it. While, however, the exact method is of secondary importance, it may still prove extremely inconvenient if an inappropriate system or designation be adopted, for it may mislead those who are not fully acquainted with the purpose of the plan and its effect.

Partners may have such various interests in an undertaking as to make the question of depreciation of great importance. A managing partner may

be paying out to a share of profits equal to that of the sleeping partner who provides the capital. It is to the interest of the first to show good annual profits without an excessive provision for future contingencies, while the second may prefer to keep his capital intact by liberally writing down out of gross profits the nominal value of the plant. On the other hand, it may be unfair to the working partner who has only a fleeting interest to safeguard the future in which he has little concern by too liberal a writing down. There are methods, easily formulated by skillful accountants, by which this difference of interests may be met, such as by an occasional review, or by providing for revaluation if the partnership be dissolved.

A reserve is generally understood to be a fund available in case of need. If it is to meet some possible sudden contingency or to equalise dividends, it is important that the fund shall be liquid in money at call or in investments easily realisable; that is to say, available without delay. If, however, it is intended only to maintain the capital value of the concern, so that it can be realised in money when the business is wound up or sold, then the reserve may, with prudent limitations, be invested in the business itself and applied to the purchase of land, erection of buildings, or in some other way to increase the manufacturing capacity of the works. If the existence of either kind of reserve be held to obviate the need for depreciation, and the original value remains undiminished in the inventory of plant, or annual balance sheet, then the designation is fallacious, for it might appear to those outside the management that the capital is intact, as well as the reserve, when really there is only one of these two available resources. Such an inference is natural even when the fund is entitled " reserve and depreciation."

While vague methods of providing for the future may be sufficient, though not wholly satisfactory, when only a few partners are concerned, they are not so in joint-stock companies where numerous and different rights have to be safeguarded. In justice to all concerned, the annual account should show the correct position of affairs, so far as experience and foresight can elucidate them. There may be as much exaggeration in writing off as in neglect to write off, and either error may cause loss to those who are uninformed about it.

While in regard to buildings, plant and machinery every branch of trade has its own special incidents so far as physical wear and tear are concerned, there are special circumstances of an entirely different kind which, from time to time, have to be considered and to which all kinds of enterprise are liable. In the great staple trades alterations and improvements become necessary which may render obsolete much of what stands in the books of accounts as of considerable value. Those concerns which have provided nothing for these contingencies by writing down or depreciating their plant, and for which the managers are unable or unwilling to provide new capital, must of need go under in the struggle with competitors better prepared.

As examples, the old-fashioned flour mills, sugar refineries, and chemical works which brought regular profits to their proprietors thirty years ago have had to be reorganised and, to a large extent, reconstructed to meet modern practice. The manufacture of Portland cement affords another example. The monopoly of the Thames and Medway Cement Works in England has been upset by Continental and American rivals, and only new expenditure on a considerable scale will bring them into line. One need hardly refer in CASSIER'S MAGAZINE to the changes and improvements in the steel-making and shipbuilding trades which have affected largely the capital accounts. These remarks might be regarded as truisms whose recital is unnecessary were it not that so many old and respectable concerns have had to pay the penalty of ignoring them.

As new kinds of machines and plant are invented and applied, proper rates of depreciation can be evolved only as experience guides. As an instance, in-

teresting questions are arising in connection with electrical apparatus and its depreciation. On the one hand, some of the materials used, such as bitumen, lead, vitrified conduits, and copper, may, if undisturbed, be deemed almost imperishable; others, liable to attrition or to rapid movement, or those exposed to wind and weather, may deteriorate quickly. During the transition period, till experience has shown the way, prudence will suggest a liberal provision not only for these physical causes, but to meet also the probability of new inventions rendering the plant valueless before it is worn out. In a period of twenty years methods of electric lighting have been entirely altered; tramways have been changed from horse traction to steam locomotives, then to cable haulage, and now a change to the electric underground conduit system seems likely to supersede many of the overhead electric trolleys so lately erected. There is a reluctance to acknowledge these risks in advance. Those who are concerned in new enterprises are assured by the sanguine inventor or engineer that finality has at last been reached, and that, in regard to renewals and depreciation, nothing need be considered beyond the mere physical wear and tear that attend all industrial plant.

A sinking fund is the form generally adopted for the recovery of capital invested in some asset wasting by the passing of time. As examples, leasehold property, patents having only a few years to run, or minerals which are becoming exhausted. If established early enough, the annual provision of such a fund may be small and can be measured exactly. There are other and less tangible assets which are also of a wasting nature, such as good-will. It has sometimes been argued, even with the support of experienced auditors, that to commence writing down the value of good-will or patents immediately after they have been purchased would be an acknowledgment that too high a price has been paid for them. It might as well be said that if a short lease has been purchased it is not necessary to institute a sinking fund to recover, at the end of the term, the capital so expended. It is true that while the duration of a lease is evidently limited, that of good-will is speculative or unknown. Yet if in any branch of trade a retrospect be made of numerous undertakings profitable twenty years ago, it will be found that a considerable proportion of them have diminished or even ceased to exist, and that the good will if now sold, would realise little or nothing. It is, however, right to mention that the courts have not always upheld the severer course here advised, for it has been decided in the case of a wasting asset that directors of a company are not bound to make a sinking fund, but may distribute their entire profits if they choose. The point urged here, however, is that candour and fairness should induc them to explain their course to all concerned.

The property in ships affords examples of both systems. The principal companies who own fleets of steamers owe much of their prosperity over a long period of years to their rule, rigidly applied, of writing down at a liberal rate the value of their vessels and of applying their revenue as net income available for dividend only when this charge has been met. According to this method not only are all repairs defrayed out of revenue, but vessels which may have cost £20 per ton are depreciated annually till they stand in the books at only £8,—a price at which they can be sold, for the usual practice is to sell old or obsolete boats and to replace them by new ones of modern design. Unless the gross profits of the undertaking would bear the cost of such depreciation, the undertaking is not really profitable, and as the period within which steamers remain in the first rank seldom exceeds ten years, the rapidity of the change affords a convenient object lesson.

The less heroic method is generally found in the joint ownership of one or more sailing vessels or tramp steamers whose destinies are conrolled by managing owners. The full income, after

defraying current expenses, including marine insurance, is all divided as profit, each shareholder being left to provide as he chooses against the reduction in value and for the loss involved when the vessel is sold at one-third or one-fourth of its original cost. So long as the circumstances are fully known to all concerned, this system is as honest as the other, for the partners are aware that they have been enjoying only a terminable annuity.

In municipal undertakings, carried out by public borrowings, there is an enforced sinking fund in the statutory condition that the loans be paid off in a given term, ranging from about twenty to sixty years, according to the nature of the enterprise. Unless repairs and renewals are liberally made out of revenue, such a sinking fund may prove insufficient, for the plant may have become obsolete or worn out before the end of the term. The tendency is to still further reduce the term where the assets are of a doubtful kind so as to safeguard not only the interests of the lenders, but those of the ratepayers who are responsible for repayment. For instance, in the case of loans raised for the specific purpose of purchasing existing horse trams a term of fifteen years has been prescribed, and that portion,—often considerable,—of a loan applied to the obtaining an Act of Parliament or to other preliminary expenses has to be repaid in five years.

Those engaged in manufacture will often plead that depreciation systems, good in theory, are impossible for want of funds. In other words, the annual writing down of values is a luxury which must be confined to prosperous concerns and limited for others to good years when surplus or exceptional profits are available. Not only, it is urged, must wages and other obligatory outgoings be met, but those engaged in the management, whether servants or partners, must be duly remunerated, and there may be nothing left.

Obviously, if sufficient be written off every fifth year, the capital may be as well, though not so symmetrically; maintained as by annual adjustment, but, at any rate, no delusion should be allowed to remain in the books of account. Plant does not cease to deteriorate because it has been worked without a profit, or even if it has been idle. If nothing has been set aside to meet the lessening value, the impoverishment is the same, though not so manifest, as if the more positive act of withdrawing savings from the bank had taken place. In circumstances such as these, shareholders must submit to the loss of income, and, when trade revives, must be content to forego some of the improved revenue till the capital of the concern has been restored. Whether they are bound to do so depends partly on the agreements of partnership or articles of association as were just referred to in the case of wasting assets.

Neglect of depreciation may, for a time, show no ill effects, especially in the early years of a newly equipped factory. Why should machines showing no signs of deterioration, and which perform their work as well as formerly, be written down in value? The young man of twenty-five sees little good in life assurance; he is as fit to-day as he was a year ago, and the matter will keep. He is, however, a year nearer his end, as he will find, on inquiry at the insurance office, where the most robust health will not save him from the increased rate of premium due to his age.

Although liberal writing down of values may, in the books of account, show diminishing assets, the proprietors are none the poorer because of book entries. If unduly depreciated, the true value will revive in a new valuation. If a proper system of depreciation be inaugurated, it will be necessary at each annual review, in order to show assets equal to the invested capital and liabilities, to set aside some of the earnings of the year to make up for the depreciated value of the plant.

It is not necessary here to describe methods of bookkeeping. Due accord between the auditors and the works manager, both experienced in such examination, will allow of a moderate, but sufficient, allowance. When the time

comes for purchasing new tools it may be urged that they are to increase the output, and not to replace machines that are worn out. Even if this be true, the new expenditure will only balance the lessened value of some obsolete machine or plant which is almost always to be found in or about a factoy. There are some machines that never wear out. They may be so strong and heavy that the operations of working have no perceptible effect on them; they may even be special tools worked only a few times yearly. A slight change in the nature of the trade or improved methods of working may still further reduce the number of occasions when the old machine can be used. Is it to be supposed that in case of liquidation such a machine will have any considerable value?

Portentous changes are looming over many engineering works. The importance of fuel economy is growing. If, as is already demonstrated, the modern gas engine is to afford power with one-half the fuel consumption of the best steam engine and at one-fourth the average consumption in the average factory, where are the funds to come from for the gas producers and gas engines if the steam engines, boilers and chimneys which must perforce be discarded stand at a high value in the books?

PROGRESS AND EDUCATION

THEIR INTER-RELATION WITH THE INDUSTRIAL ENGINEER

By H. F. J. Porter

HISTORY and observation tell us that the world advances. By "the world" we mean the sphere of human activity, which has evolved from prehistoric barbarism to the civilisation of the twentieth century, and by "advance" we mean this same evolution, and include in it progress along moral as well as material lines, for experience teaches that these two attributes are interdependent; hence, real progress cannot be made when they are not harmonious. Advance, however, cannot be continuously progressive, for existing conditions are complex, and, at times, antagonistic. Under the latter circumstances a strained situation is relieved either by a relaxation of effort, producing pause, or by a break, which may bring about a retrograde movement. But either of these effects is only temporary; as soon as equilibrium is established, progress begins again. There seems to be this persistent purpose running on through the ages.

That this world advances is because the resultant of the vital forces that are at work upon it tend to move it forward. And as progress continues, its rate constantly increases, because opposing forces are gradually changing their direction. These latter forces constitute the efforts of the ignorant, fearing that the adoption of ideas which contribute to the advantage of the many may tend to injure their individual interests.

Thus the forces that make for and against progress consist, as society is constituted, of the broadly cultured on the one side, who become the active or positive element in the promotion of affairs, and of the more or less ignorant on the other, who become the resistant or negative element, and whose efforts to obstruct must needs be met and overcome before there is any advance. Therefore, progress will be most rapid and permanent when the greatest number of people are educated sufficiently to know that their interests will be enhanced by participation in those activities that conduce to the public welfare. Intelligent effort is successful in the long run; "truth is mighty and will prevail," and the permanent strength of a nation can always be

gauged by the character and quality of the education given to its masses. These conditions not only are now alive, but that they have existed in all countries from time immemorial will be evident by a brief revision of the past.

From ethnological study and our observations of the habits of barbarous tribes of the present day, we infer that some sort of education must always have existed among men even in early times. Crude, no doubt, it must have been, because of a character commensurate with the habits of the people. At first it was of a purely practical nature in methods of attack and defence for self-preservation from human foe and wild beast, and in means of obtaining food for sustenance. As a consequence of this and because, during the long ages in which the faculties were being developed, there was no humane teaching, the brutal instincts inherent in the race were not eliminated, and are even now only dormant.

Man soon found that strength lay in numbers, and the earliest "trust" was the tribe where many individuals with like interests confided them to the most capable warrior, who, in turn, selected his captains to assist him in their management. Man thus became gregarious, and the individual training of the youth was according as the tribe was nomadic or settled, predatory or pastoral in its habits. Then, as their free life brought the people face to face with Nature and her mysteries, there was evolved an emotional and religious spirit that was worked upon by some of the more crafty and less competent individuals to wrest control from the established leader. Subsequently these two factions compromised their differences and put forward the deified ruler, who, in the original form of monarchical government, became the head of the Church, as well as of the State and army.

Here we see the beginnings of that paternalism of which the essential characteristics have been the basis of all systems of organisation and government, both of a public and private nature, until the present day. Educational ideals that then prevailed were derived from the principles that controlled both the national pursuits and religion. A system of schools need not have existed; but there must always have been facilities for instruction in the family, the society, and in religious organisations, besides the direct discipline enforced through crude laws, civil and military.

In religion there is implied a definite fundamental view of the world which is referred to in all social relations, and thus is obtained a systematic unity in the details of everyday life. As the monarch held sway, largely through his accomplices by imposing upon the credulity of his subjects, he was careful to see that the latter were not too well educated. Instruction assumed an esoteric trend, and was confined to the privileged class. The dicta of the priests were shrouded in mystical language, and where the populace was of low intelligence, it was swayed by oracles, omens, and signs, construed to suit the designs of the State.

When power fell into the hands of the unscrupulous, there grew up religious ceremonials, mixed with voluptuousness and luxury, which gradually led to effeminacy in those holding control, resulting in relaxation of effort, and to decay in the national institutions. Then new peoples took their place, and, profiting by the failures of their predecessors, rose to a superior height before they, in turn, through ignorance of the basic principles of political and social science, yielded to degenerating influences. Though great and noble institutions were founded in the name of exalted ideals, which for a limited period gloriously flourished, these very institutions have, in the course of time, become the instrumentalities which gradually demolished and obliterated the ideals for which they once stood. The history of nations repeats itself along these lines from the earliest down to the present time. In this process of evolution we see the inception of the privileged class, which, later, in more democratic forms of society, became generalised as "capital," and which, by an equally divine right, is supported by the subordinated masses, whose existence, other than as a neces-

sary evil, is scarcely recognised in return. Little is known of the early civilisation of the ancients, but the wonderful prehistoric temples of the Armenians, Chaldeans, Persians, and Babylonians recently excavated leave room for doubt neither as to the high state of culture of the upper classes of these great nations nor that there must have been some unstable feature in their domestic or foreign relations that allowed others to overpower and sweep them into oblivion.

Thus, also, the mystical and theologico-philosophical teachings of the Egyptians, Greeks, and Romans finally led to moral decay, and, in turn, cost these nations their supremacy. In India, Japan, and China similar systems, but based on more ethical principles, have, by developing a class distinction, operated to retard progress. It is true that the national institutions of some of these countries have shown remarkable results in producing philosophers, poets, statesmen, and scientists. We have as evidence the writings of the Greeks and Arabians still extant and unsurpassed in astuteness and diction; also the development of algebra and geometry, and discoveries in astronomy; witness, also, the knowledge of chemistry possessed by the Egyptians, enabling them to embalm bodies and colour their edifices so that the results of their work are as perfect now as when first produced. The fine arts also, through courses of instruction in architecture, sculpture, painting, and music, reached a height never since approached. It must be noted, however, that there could have been but a limited number of individuals whose talents and inclinations would induce devotion to the studies of these professions, while the masses, being neglected, remained in a condition of semi-servitude. This lack of co-ordination gradually led to disaster in times of national peril, and finally to total disintegration.

The first four centuries of the Christian era witnessed the decline of Rome with her pagan institutions of learning, and the slow introduction of Christian teachings. Then, as a result of barbarian inroads, there followed seven hundred years of confusion and intellectual darkness, illumined only by sporadic efforts of the civilisation of the past to rehabilitate itself. The success of the Arabs in extending the enlightening influence of the Mohammedan faith at the point of the sword was destructive rather than constructive in its results; in religious wars bigotry seems to blight all reason.

The losses of the seminaries in Palestine and Egypt, and especially of the library at Alexandria, at the instance of the Caliph Omar, were never redeemed to posterity, even by the founding of Moslem colleges in those countries, and as far east as Cordova, in Spain. The only institutions that continued to exist in Europe throughout this period were the castle and the monastery, with their products, respectively, of the knight and the monk.

By the middle of the twelfth century the new nations had sufficiently established themselves to require a system of education in order to supply material to support their civic and religious institutions. Embryo universities were founded, first in Italy, and then gradually in the other Continental countries.

Three centuries of instruction by itinerant teachers had passed, however, before the effect of enlightenment was felt upon the dense ignorance in which the whole Continent was plunged. Then gradually the submerged intelligence of the best minds asserted its independence, and, emancipating itself from the feudal despotism that had so long held sway, developed what was original in educational ideas by the light of classic arts and letters. Such institutions as grew up, following the example of their predecessors, became essentially schools for the privileged few, dominated by ecclesiastical authority where learning depended largely on memory and unreasoning acceptance of whatever the Church considered safe to be divulged.

This was the Renaissance, and served as an intermediate step in the progress of education towards the Reformation in the sixteenth century, when a successful effort resulted in throwing off the yoke of scholasticism which had drawn men away from the world and under which progress had so long languished. Here

was conceived the art of printing, and the slowness of its adoption illustrates the condition of the mechanic arts in these times.

From this time modern education may be said to date its growth. Beginning with Lord Bacon, there follows a long line of educational writers and practical teachers, to mention all of whom there is not space here, while to name any would create unfair comparison with the rest. Many of these men were instrumental in establishing schools which not only acted as feeders to the universities, but incidentally implanted in the minds of the common people a desire for learning.

In the seventeenth century England began to found colleges in her American colonies, her methods of instruction in them being based on the same general principles that had been adopted in her universities at home. The object of all these institutions of learning was to acquaint students with what was deemed culture as embodied in the languages and literature of ancient Greece and Rome, together with some knowledge of mathematics, geography, and general history. In other words, general culture was considered synonymous with classical scholarship. This type of education was intended primarily to meet the demands of the aristocratic organisation of society in England and its supposed counterpart in America.

In such courses of instruction, however, depending, as they did, mainly upon the exercise of memory, there could be but little exercise of the originative faculties, and a class of conservative and non-progressive people was thus developed whose thoughts and actions were based largely on what was considered the best, but, in fact, belonged to, and fitted, a civilisation already long past. No thought was given towards improving the mental condition of the masses; the importance of the latter in the industrial and commercial interests of the nation not being yet appreciated.

The situation is aptly described by Sir William Berkely, Royal Governor of Virginia, who wrote home in 1671,— "I thank God there are no free schools or printing; for learning has brought disobedience and heresy and sects into the world, and printing has developed them and libels against the best government. God keep us from both."

From the fifteenth to the nineteenth century progress was slow. Established precedent in all lines was closely adhered to, and it was not until after the beginning of the nineteenth century that the rate of advance became at all notable. It was stated above that modern methods of education began with the Reformation. The expression "modern" was used advisedly, for the curriculum in the large universities of today differs little from that of four hundred years ago. No changes were made in subjects taught and in the methods of teaching up to one hundred years ago, and those that have been made since then are by no means commensurate with the progress that has taken place in the world of human activity. Institutions which draw their inspiration through roots that run back far into the Middle Ages are, and must of necessity be, too old and rigid to respond readily to the requirements of what during the last century has developed into practically a new civilisation. These institutions have been jealous guardians of the learned professions of theology, law, and medicine, and the mould of tradition that has accumulated upon them has become an impenetrable and inflexible armour. It has, therefore, been rather past their doors than through them that modern progress has led.

Germany was first to feel the necessity of providing instruction better suited to the needs of the times and for those who were taking an active part in promoting the material welfare of their country. The "gymnasia" were established early in the last century as preparatory schools for the universities, and later the "Real-Schulen" for those who did not desire to take the university courses.

The public school system was established in the United States shortly after the initiative taken by the Germans. This system, which first presented an opportunity for trained teachers to prove-

their ability, soon sprang into favour, and at the present day the best schools in the country are included in it. The polytechnic school, which had its inception in Germany and France, and was established later in the more progressive Continental countries, made its practical utility at once apparent in supplying scientific training to a class of mind which had heretofore received no encouragement. Similar institutions were established in the United States about the middle of the last century to meet a like need there, but the United States Land Grant Act of 1862 offered the first great opportunity for the encouragement of learning in those branches of knowledge, the possession of which make for commercial and industrial progress. Since then the older American colleges, recognising with apparent reluctance the important bearing of scientific attainments upon civilisation and progress, have grudgingly added technical instruction to their courses.

It is unreasonable not to concede to the technical schools the credit in large part for the great progress that has taken place since their establishment. Before that time there was no recognised purpose for the systematic collection and analytical tabulation of scientific data from which laws could be formulated, and knowledge was, therefore, wanting by which original investigation could be made. Man groped about in the dark, seeking, by repeated trial and failure, to find the way, and his natural tendency to cling to tradition was fostered by defective principles of education, which delayed the development of his originative faculties. It would seem as if ideas and beliefs imbibed from the early instruction of parents or teachers are almost ineradicable in maturer life. And since intolerance is instigated and stimulated by ignorance, any effort to depart from precedent was looked upon with suspicion, and, as far as possible, was checked. Thus, the times, being buried in empiricism, clung to tradition, and progress, led by error only, halted from disparagement.

As soon, however, as the techicnal schools were established, their influence upon the arts and sciences became evident. The natural inclination of similarly educated minds to come together for interchange of thought brought about the technical societies, and the discussions which there took place were disseminated by the technical press that sprang into existence. Then dormant minds awoke, latent thoughts were expressed in action, and misdirected energies were correctly applied. Scientific deductions, drawn from the results of investigation, enabled men to begin to reason with some knowledge of the principles of causation and sequence, and advance along original and independent lines became active in all industries.

Instigated by an inborn prescience of the enormous possibilities of the future demands of commercial life, men devoted their lives and fortunes to improvements in methods and processes of manufacture. This activity was especially marked in the iron and steel industry, owing to the prominent part which it seemed forced to take by the universality of the usefulness of its product. Many overcame their prejudice against rough work, and directed their energies to subdue the forces of Nature.

There seems ever to exist a type of character that thrives on opposition; it is stimulated to action when the opposing current is strongest, and stems it against all obstacles; the situation develops the man. Among the strong and rugged figures that impressed their personality upon these times were some who, divesting their minds of the trammels and precedents that existed, struck out for themselves, and developed and perfected the pneumatic process of making steel, now known as the Bessemer process. It has been said, and with much plausibility, that to-day civilisation owes more to this process than to all previous inventions of man put together. Thus the industrial development that followed the contemporaneous beginnings of technical training and practical work in the mechanic arts proved the importance of science in relation to the progress of a nation, and that the intimate blending of theory and practice lies at the root of all industrial

success. In the severe competition which has since grown up in all lines of commercial and industrial activity strenuous effort has been made to improve product, and, at the same time, to reduce cost. The attempt to accomplish these results has not only brought about a strong demand for men of wide knowledge which develops originality of thought, but, on the other hand, has forced out of employment men who are not thus equipped. This condition of affairs has brought about the necessity for a change from the old lines of educational preparation for life in order that man can become better equipped to take an efficiently active part in it. The fact that the majority of those who are prominent in the affairs of the day have not graduated from courses in the older and larger colleges devoted to the so-called learned professions, in itself implies that these courses are not necessary adjuncts to a qualification for the active operations that are going on about us. When we scan the records of these so-called "captains of industry," we find that the preparation for their work was obtained largely by participation in it. And this is because there has been no institution of learning that has met the requirements of the times and prepared men for service in the world of industrial and commercial enterprise.

Although during the past fifty years many thousands of factories, mills, workshops, and other establishments of an industrial nature have been projected and successfully operated, there is not as yet a single educational institution in which the theory and practice of shop organisation and management are taught. There has been, however, a small body of men who, favoured by a combination of opportunity and proper qualifications, have studied the industrial problems which they have encountered in their daily environments, and, by teaching how they may be solved, have done efficient work in a large and ever growing field. That this field is ready for the work of these industrial engineers is shown by the demand in which their services are held.

In finance and commerce likewise, there has been no institution where preparation could be made for positions of responsibility in banking and mercantile establishments. The same is true of the calling of the statesman and the diplomat. Yet the men who have grown up in these professions, with their now rapidly expanding fields of influence, are determining the industrial supremacy of nations.

The science of medicine also, as heretofore expounded, has been brought into disrepute by discoveries in the laboratories of the bacteriologist, and justice has been more often defeated than attained through the cumbersome and procrastinating methods by which the law has been administered, according to the code.

It is very evident to the most casual observer that more good is being done to humanity by the practical religion of the day than through mere adherence to dogma and creed as taught in the schools of theology, and that there are more ways of serving God than through the calling of the church.

Of late, therefore, there seems to have been an awakening on the part of the students of political and social science to a realisation of the fact that the prestige of the older professions is on the wane.

It is useless longer to attempt to force mediæval ideas on a world that is reaping the benefits of modern thought. The stream of progress will not flow backwards to accommodate antiquated theories. There are industrial problems, religious problems, social problems, and their solution will be found not in legal enactments, not in the sciences, not in dogmas, but in a more generous application of the principles of cause and effect.

The question is asked, how much has national progress been delayed by the tardiness of mankind to destroy what is known to be false because nothing is presented to take its place. We are learning, however, that the false merely obstructs our vision, and that we have only to tear it away, when recognised, in order to reveal the truth just beyond. So now, more than ever, is human reason unfettered by tradition and the dicta

of authority, proving all things and holding fast only to that which is good. This new impulse in the world of human activity has convinced the student of pedagogy that methods of instruction now in vogue are totally inadequate for present needs, and that the relation of the teacher to the world of progress must be made more clear. It is obvious that conditions cannot be cured merely by denying facts, but that some definite action must be taken in the premises.

It is gratifying, therefore, to find the subject already under discussion in publications and at the meetings of those whose mission it is to direct thought and action in the councils of the pedagogue. It is becoming understood, and the knowledge is being acted upon, that the possession of attainments does not necessarily confer the power to impart them to others, and instead, therefore, of leaving instruction to novices, destitute of any training, and acting only on the memory of the defective methods under which they themselves were reared, it is directed by graduates of schools where the theory and practice of teaching are expounded.

We find, too, in some of the primary and secondary schools, both public and private, from the doors of which so many of the foremost men have emerged to enter their active careers, that there has been a complete recognition of the fact, that in order to be successful in the present severe competition, a man must have capabilities better than, or at least equal to, those possessed by others in the same line of work. Means are, therefore, being devised so that the youth of the day may discover as early as possible in his career what may be the natural trend of his inclinations and abilities in order that he may develop them to their fullest extent as he grows older, and thus become an expert in the use of the endowments with which he has been provided by Nature. To accomplish this result, it is proposed to open to him as rapidly as possible the world of culture as we now understand it, and to lead him into those paths which would naturally arouse his curiosity and interest, for in these his desire to find out the reason for things will give him an incentive to surmount the obstacles which he is bound to meet as he progresses.

Thus is an effort made to develop the faculties that are latent, rather than to follow the older methods leading in the direction of implanting talents which may, and often do, not exist. In the one case endeavour is directed towards encouraging as many as possible to survive, while in the other, the law of the survival of the fittest is left to work untrammeled. By this means the exceptional man may be discovered and his powers developed for future research work in the higher institutions of learning now being planned. To carry out this method of developing the youth of the day, teachers are needed who are capable of recognising and appreciating the significance of early and natural tendencies in order to encourage further self-revelation. In other words, the aim of the modern school should be to prevent the misdirection and consequent waste of energy in the life of the individual; otherwise "the opportunity is as surely gone as water that has passed the mill." Care must, however, be exercised that not only professional efficiency is thus attained, but that cultured manhood may at the same time be acquired.

To achieve success in life in any direction, a man must be more than a mere technist. To understand his own profession he must appreciate its relation to all others and its position in the world of progress. To the thoroughness of detail acquired by the specialist must be added the broad grasp of affairs which comes with general culture and a daily contact with men and things.

This Mr. Robert Moore, in his presidential address at a recent convention of the American Society of Civil Engineers, denominated as the resultant of the reaction of a man's inheritance upon his environment which we sum up in the word "character."

Here, then, according to Professor Schurman, president of Cornell University, is a preparation for life through a dual system of studies of which one

branch teaches of matters material, and the other of human affairs; and as the proper study of mankind is man, the latter is more important than the other, and these studies should be made effective by interesting the student to contemporaneously participate in their practical application. By far too many men content themselves with a superficial study of the theories of economics, of political science, and of ethics, while others, who have not had the same advantages of education, by daily contact with the institutional life of organised society, rise to superior heights in the world of influence. An authority on the subject, Professor Paul H. Hanus, of Harvard University, in a recent address, said:—

"The education demanded by a democratic society to-day is an education that prepares the youth to overcome the inevitable difficulties that stand in the way of his material and spiritual advancement; an education that, from the beginning, promotes his normal physical development through the most salutary environment and appropriate physical training; that opens his mind and lets the world in through every natural power of observation and assimilation; that cultivates hand-power as well as head-power; that inculcates the appreciation of beauty in Nature and in art; that insists on the performance of duty to self and to others; an education that in early manhood, while continuing the work already done, enables the youth to discover his own powers and limitations; that impels him, through oft-repeated intellectual conquests and other forms of productive effort, to look forward to a life of habitual achievement with his head or his hands, or both; that enables him to analyse for himself the intellectual, economic, and political problems of his time, and that gives the insight, the interest, and the power to deal with them as successfully as possible for his own advancement and for social service; and, finally, that causes him to realise that the only way to win and retain the prizes of life, namely, wealth, culture, leisure, honour, is an ever increasing usefulness, and makes him feel that a life without growth and without service is not worth living."

Another representative teacher, Dr. N. M. Butler, president of Columbia University, in an address at Vassar College, had this to say:—"I offer as evidences of an education, correctness and precision in the use of the mother tongue, refined and gentle manners, which is an expression of fixed habits of thought and action; the power and habit of reflection; the power of growth, and the efficiency, or power, to do."

So we see that the pedagogue of the present day insists that the preparation for life is less an effort at mental attainment than a development of character. The Rt. Hon. Sir John E. Gorst F. R. S., president of the Educational Science Section of the British Association for the Advancement of Science, at its recent Glasgow meeting, thus expressed his conception of the situation:—

"The character of a people is by far its most important attribute. It has a great deal more moment in the affairs of the world and is a much more vital factor in the promotion of national development and influence and in the spread of empire than either physical or mental endowments."

After carefully perusing the recent writings of representative teachers and reviewing the proceedings of their meetings, it is evident that the trend of their recommendations to schools and colleges is to give to their pupils a general knowledge of the history of the development of society, emphasising the basic and underlying causes for the various steps in progress, rather than dwelling upon the characteristics of the various war heroes of the past; to use this knowledge in promoting the self-discovery and development of the student's dominant interests and powers, not only seeking to render attainments as rapidly as possessed available for devotion to life's serious purposes, but to use them as an aid to contemporaneous participation in the refined pleasures of life.

These radical ideas are not only being rapidly disseminated, but are taking root in unexpected places. The social

scientist, the liberal religionist, and the other forces that are active in the social and religious reforms of the day, already recognise an awakening spirit of fellowship. The narrow religion of a few years ago taught that the adherence to a creed or dogma was the sole essential of salvation. A broader interpretation of the sacred writings of all religions shows that their aim, when stripped of form and ceremonial, is to encourage man to uplift his fellows. We have learned by experience to do this, not by indiscriminate charity, but by showing men how to help themselves and by lending a helping hand when necessary.

These are the principles which are being injected into business management and operations. Character, developed along these lines by early instruction in the schools, will aid in minimising forces that operate to retard progress. When specific difficulties arise, we may depend upon the situation developing the man with the necessary mental qualifications to surmount them. The results of our actual experience as we go ahead should now be carefully formulated by those best qualified as analysts to do such work, and courses of social science introduced in the colleges so that men who manifest a possession of tact, fair-mindedness, and executive ability can, by a study of the data presented, prepare themselves for positions of a business character.

As before stated, there are industrial engineers now in the field, well equipped with this special knowledge, whose services should be employed in the courses of the proper institutions to elucidate the ethics of modern business methods. The potential of position presents to no one as favourable an opportunity for wide influence as to the employer of labour, and especially to the manager of a works, and this influence may bode good or ill to the men employed, to those who are financially interested in the enterprise, to the community in which the works are located, to the industry of which the company is a unit, and to the world of progress which that industry is doing its share to promote, all depending upon the qualifications for office displayed in active management.

For efficient administration of the complex duties of such a position there is necessary the preliminary training of the industrial engineer which includes, besides a thorough acquaintance with the details of manufacture of the special product and the relation which the output of the works bears to the demand and supply in local and foreign markets, an accurate knowledge of the methods and cost of production, not only by the works in question, but by competitors. One man cannot be expected individually to make investigations so as to keep himself thoroughly apprised of what is going on in these various directions, and he must, therefore, depend upon others to keep him advised. His ability to surround himself with capable assistants will, therefore, be a measure of his success, and this ability will depend largely upon his own character as a man. It will not be whence he sprang nor what he believes, but what he is, that will tell in the long run. The manager must be sufficiently master of the situation to dictate a policy which shows resolute firmness of purpose not only in dealing with employees, but with clients, competitors, and the local community. Conditions must be confronted rather by a state of mind than by set opinions.

People should be met and questions discussed in a spirit of broad charity, of great-hearted sympathy, of willingness to give help and accept it in return, ever keeping in mind a desire to do that which is right without mental reservation. By assuming such an attitude, respect can always be exacted, because, where similar conditions exist, it is willingly yielded.

The duty of a corporation, like that of the individual, is of a dual nature, viz., towards itself and towards its neighbour. Its duty to itself comprises the necessity of turning out its product cheaply and at the same time excellent in quality. To fulfil these requirements the management must see that the component factors of production are kept in prime condition. The more intelligent the employees and the more efficient

their facilities for production, other things being equal, the cheaper and better will be the resultant output.

Its duty to its neighbour requires that it should do its share in raising the standard of the community in which it is located. The establishment of a works in a town entails the responsibility of bringing into it employees and their families. These people, unless properly housed, may disseminate crime and disease, and, through the attendance of the children at the local schools, will tend to lower standards already existing. These responsibilities are not always appreciated because not understood by the management.

The manager who lives in luxury, without seeming to care for the condition or welfare of his employees, rouses antagonisms which are not conducive to collaboration with his interests either in the works or in the community. There is nothing that will shake faith in honesty of purpose and uprightness of manhood more than the cheap shrug of indifference accorded to an appeal for more conscientious consideration of the dual duties here enumerated.

Many measures now accorded as beneficial to both employer and employed by those who recognise their advantages are used by novices in management for advertising purposes, and miss, to a large extent, the object of their introduction. Sentimentality and the spectacular must be avoided in the performance of public offices as in acts of a private nature. Nor should zeal outrun performance, for as President Roosevelt aptly expresses it, "as much harm is done by soft-headedness as by hard-heartedness." The paternalism of the past must be modified and provision made for those conditions in which self-reliance and independent manhood can thrive.

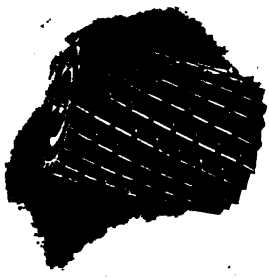
Systems of payment for work by which the individual is rewarded according to his merit encourage ambition. A bonus given for excellence of attainment and for improved methods of accomplishment inspires originality and develops improvement.

The time has come when the antagonisms of labour and capital should exist no more. The trust, as well as the trades union, must learn that restriction of output,—the cardinal principle of their creed,—is unnatural in its fundamental application, as it destroys personal ambition, which is one of the basic elements of progress. The labour cost of an article is of no consequence as a factor in the equation of manufacture. Economy of production is cheap or dear, according to the interest charge which each unit of output must bear. The employer and the employed, educated in the same school, should work together on the same platform and to the same end.

These ideas are being injected into modern business methods by the industrial engineer. His position in the world of progress is daily becoming more influential. It will not be long before his status will be recognised, and when the elementary principles of his calling are taught in the public schools and advanced courses are established in the higher institutions of learning, then will the world advance most rapidly and steadily to its ultimate goal, whatever that may be, through the adoption of the principles of that broad fellowship which tends to make men work together for their common good.

MILLING MACHINES IN THE UNITED STATES

By Chas. S. Gingrich, M. E.



A MODERN MILLING CUTTER

WHEN, more than half a century ago, the ingenuity of the Yankee gunmaker devised a machine that could be substituted for hand labour in the manufacture of the irregularly-shaped parts entering into the mechanism of firearms, the first step toward the successful duplication of gunparts was accomplished. The subsequent, rapid perfection of these early machines, and the successful production of properly formed cutting tools for their equipment marked the final step.

Then came that bitter struggle for the preservation of the Union; and, while New England homes were furnishing men, New England armouries were furnishing guns, guns made by the newly-perfected process of milling to exact form and gauge, which alone made possible the production of the many hundreds of thousands of small arms that were supplied to the Union armies by the government and private armouries. After the Civil War, the manufacture of sewing machines for household use became an extensive industry which required the same methods of manufacture as the making of firearms, and through it the process of milling was rapidly advanced and gradually adapted to the general manufacture of machine parts.

There are records of a primitive hand milling machine that was used in Connecticut at the beginning of the nineteenth century, and of milling machines with power feed that were used in armouries in the forties. Important improvements were made on the latter about 1850, by one C. McFarland, but his machine still retained the rack and pinion feed arrangement, and was replaced four years later by the Lincoln miller, which " embodied the invention of a screw feed with quick-return hand motion." The original designs of this machine were made by the late Francis A. Pratt, while superintendent of the Lincoln Foundry and Machine Co.; hence, the name " Lincoln Miller." The rack feed machines did not have an even table motion and were used only for roughing-off the pieces to be afterwards filed to size and finish.

All this was changed by the even motion of the screw feed Lincoln miller, on which, when equipped with "gangs" of cutters, the then exceedingly difficult feat of milling irregularly shaped gun parts to gauge was first successfully accomplished by one Gilbert A. Bush, who also made his own cutters, which gained for him quite an extensive reputation as a tool maker. Such is the early history of the Lincoln miller, which is also the early history of the duplication of gun parts on the milling machine.

This type of machine is largely used to-day in the manufacture of firearm, sewing machine, and typewriter parts, and work of a like character where large quantities of similar parts are to be milled. Usually a machine is set up to perform a single operation, the work being passed through as many machines as there are operations to be performed. The method of making adjustments on these machines is somewhat tedious, and their field of usefulness is therefore confined entirely to the duplication of small parts.

Fig. 1 shows the present style of the

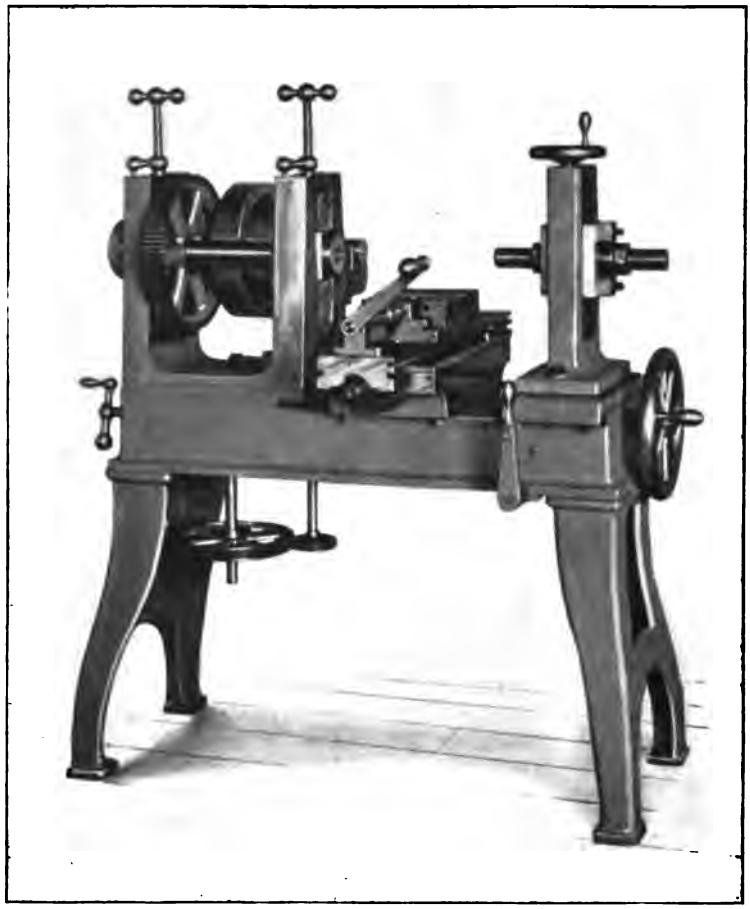


FIG. 1.—A LINCOLN MILLER, AS BUILT BY THE PRATT & WHITNEY COMPANY, HARTFORD, CONN.

Pratt & Whitney Lincoln miller, the general design of which differs but little from the original machine. The fact that this company alone has made over 7000 of these machines gives one an idea of their extensive use. A recently designed tool of this well-known type has just been brought out by the Hendey Machine Company, and is shown in Fig. 2. It has a six-speed feed-changing device, driven by a two-step cone, giving 12 changes in feed, ranging from 0.006″ to 0.065″ per revolution of cutter. The machine is equipped with an oil pump and provided with a large pan which drains into the reservoir beneath.

Fig. 3 shows a miller, made by The Grant Tool Company, which is especially interesting in the method of making the vertical adjustment. This is accomplished by means of a handle shown in front of the head of the machine, through the medium of a worm and worm wheel, enabling the operator to make the finest vertical adjustment of the spindle. This feature makes the machine adaptable to a large variety of work.

Figs. 4, 5, and 6 illustrate examples of what is commonly known as the planer type miller. These machines are now quite common in railroad, locomotive, steam pump, and electrical, as

well as machine tool shops where they are performing the operations that were formerly done on heavy planers, on widely varying kinds, shapes and sizes of machine parts.

The machine shown in Fig. 4 illustrates one size of four-head milling machine, made by the Ingersoll Milling Machine Company, and an idea of the size of the largest of these machines can be gained from the following figures which apply to the 81-inch miller. The table is 73 inches wide by 15 feet long. It will take in work 82 inches wide and is 40 inches high from the top of the table to vertical spindles. The total right-hand vertical spindle has an automatic reversible feed across the machine.

By reason of this combination of four spindles, both horizontal and vertical, together with a wide range of adjustments, this style of machine is particularly well adapted to a great variety of work. The machine just described is shown in operation in Fig. 26.

A miller of the same type, but having only the two vertical spindles, made by the Niles Tool Works Company, is shown in Fig. 5. This machine is well adapted to profiling, the spindles having a 6-inch vertical adjustment, with power cross feed, and each saddle carries a

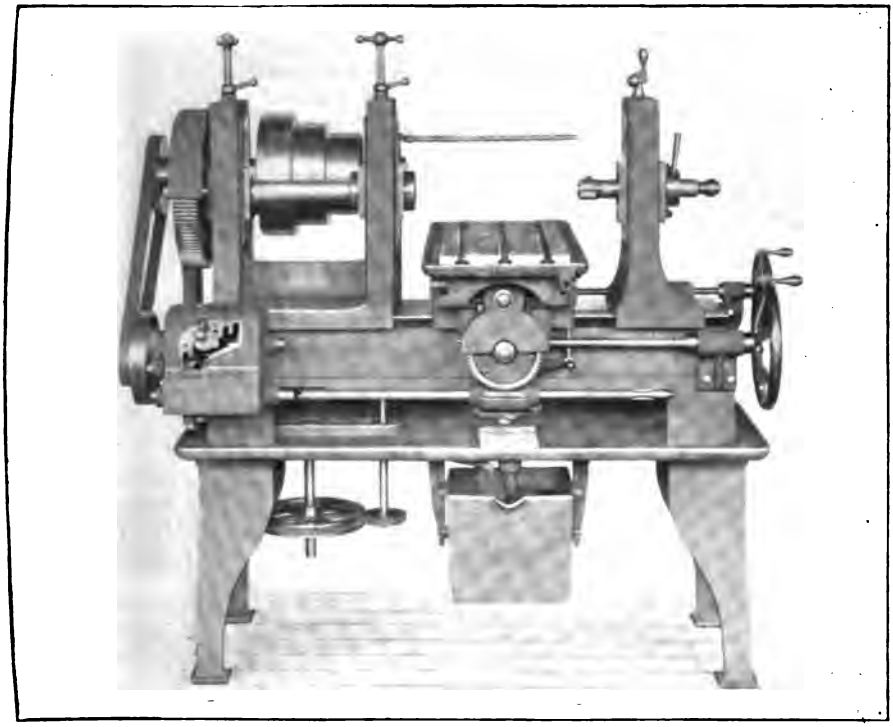


FIG. 2.—A LINCOLN MILLER BUILT BY THE HENDEY MACHINE COMPANY, TORRINGTON, CONN.

weight of the machine is approximately 15 tons. The table has the Sellers drive and has a feed range of from 3-16 inch to 10 inches per minute. All four heads can be driven at once; the horizontal heads can be driven independently of the vertical, and vice versa, and the former or copying attachment. The table is 20 inches wide and is driven by a spiral pinion and rack, insuring the steady movement which is so essential to successful milling.

Another machine made by the same company is shown in Fig. 6. This is

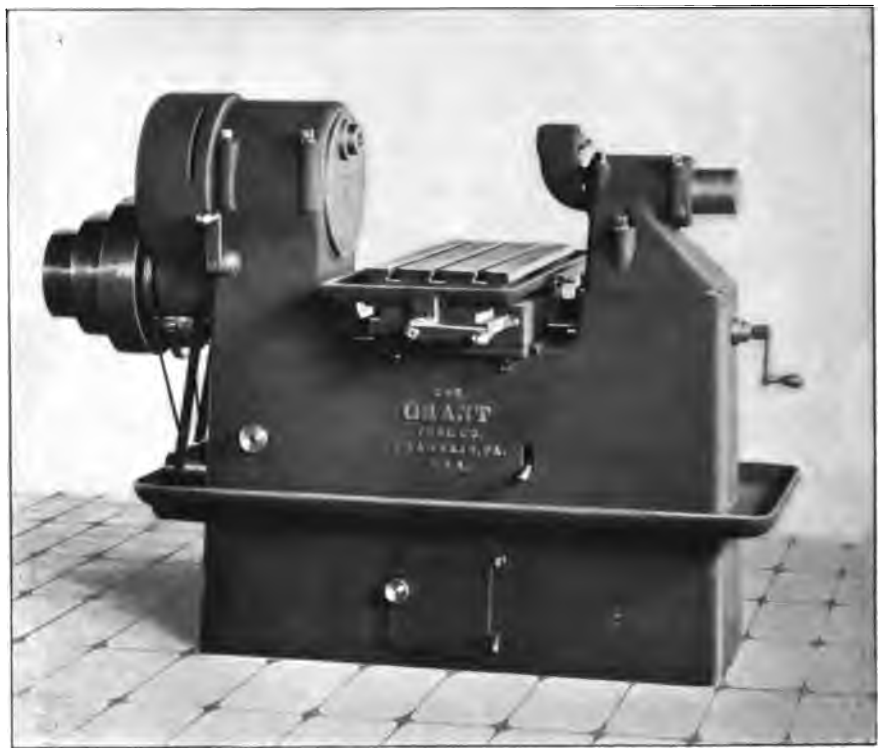


FIG. 3 —A MILLING MACHINE MADE BY THE GRANT TOOL COMPANY, FRANKLIN, PA.

a good example of the class of machines which are commonly known as " slab millers." It is now generally conceded that the limiting factor of milling operations is determined by the strength and durability of the cutter. These are greatly extended by having a thoroughly rigid frame and a powerful driving train for the feed of the machine.

There is no class of milling that meets with failure so often as the apparently simple operation of slabbing. The immense stress imposed on the machine by the great width of cut that it is expected to take, invariably causes chattering to an alarming degree,—the great bug-bear of milling to the inexperienced operator. The only solution of the problem lies in the proper selection of cutters, the use of a fast feed, and a machine of ample proportions to stand the strain. The liberal proportions of the machine illustrated in Fig. 6 show careful consideration of all these factors on the part of the designer.

It may be interesting to note in passing, that the Ingersoll Milling Machine Company makes a slab miller, which, while it still retains the general form of a planer, does not have a cross rail nor a top rail, the spindle housings being mounted directly upon the uprights, the upright carrying the outer end of the arbour being removable, making the machine " openside," which is of decided advantage for face milling pieces of large size.

The machine shown in Fig. 7 is made by the Pratt & Whitney Co., and marks a step in advance in the evolution of the planer type miller. Here the cross rail and top rail are absent; the housings have developed into wide faced, substantial columns, secured to a large base, the entire framework being sufficiently rigid not to need the top tie bar. The feeding and elevating mechan-

isms are placed at the front of the base; operating and adjusting levers are within easy reach of the operator, which greatly adds to the convenience of handling. The heads may be operated and adjusted simultaneously or independently, to suit conditions, and the uprights can be adjusted to and from the table.

A double horizontal spindle, or duplex miller made by the Beaman & Smith Company, is shown in Fig. 10. Both spindles are driven at the same speed, by one belt, with ten variations in speed, ranging from 9 to 32 revolutions per minute. The spindle heads are adjustable, horizontally, to and from the table and can be set to a minimum distance of 4 inches and a maximum distance of 48 inches between the ends of the spindles. The table has a longitudinal screw feed of 48 inches, is carried by a vertically adjustable knee providing 11 inches vertical adjustment, and the rate of feed can be varied from 1 to 6 inches per minute.

An excellent example of the modern "column" type of vertical spindle miller is shown in Fig 8, a machine built by the Brown & Sharpe Manufacturing Co. This type of miller may be considered broadly as a heavy form of profiling machine and finds its best application in profiling operations, using face or end milling cutters. The use of surface mills, which on this machine are used for finishing the edges of the piece, is very limited because of the difficulty of supporting the outer end of the cutter arbour, and consequently such operations are almost entirely confined to surfaces that can be covered by

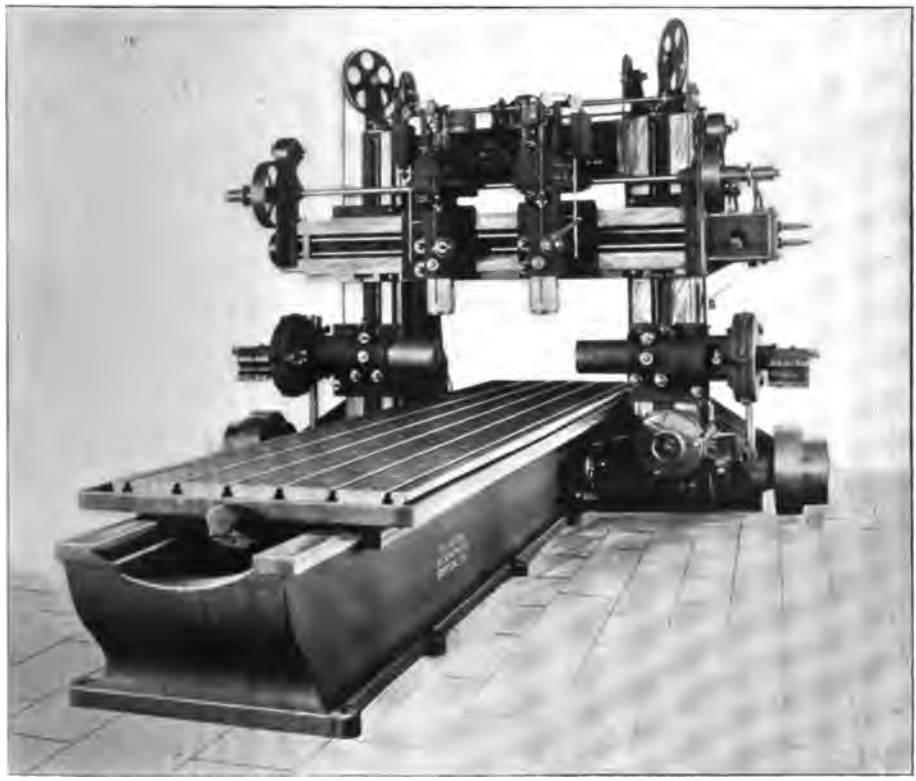


FIG. 4.—A FOUR-SPINDLE PLANER TYPE MILLER MADE BY THE INGERSOLL MILLING MACHINE COMPANY, ROCKFORD, ILL.

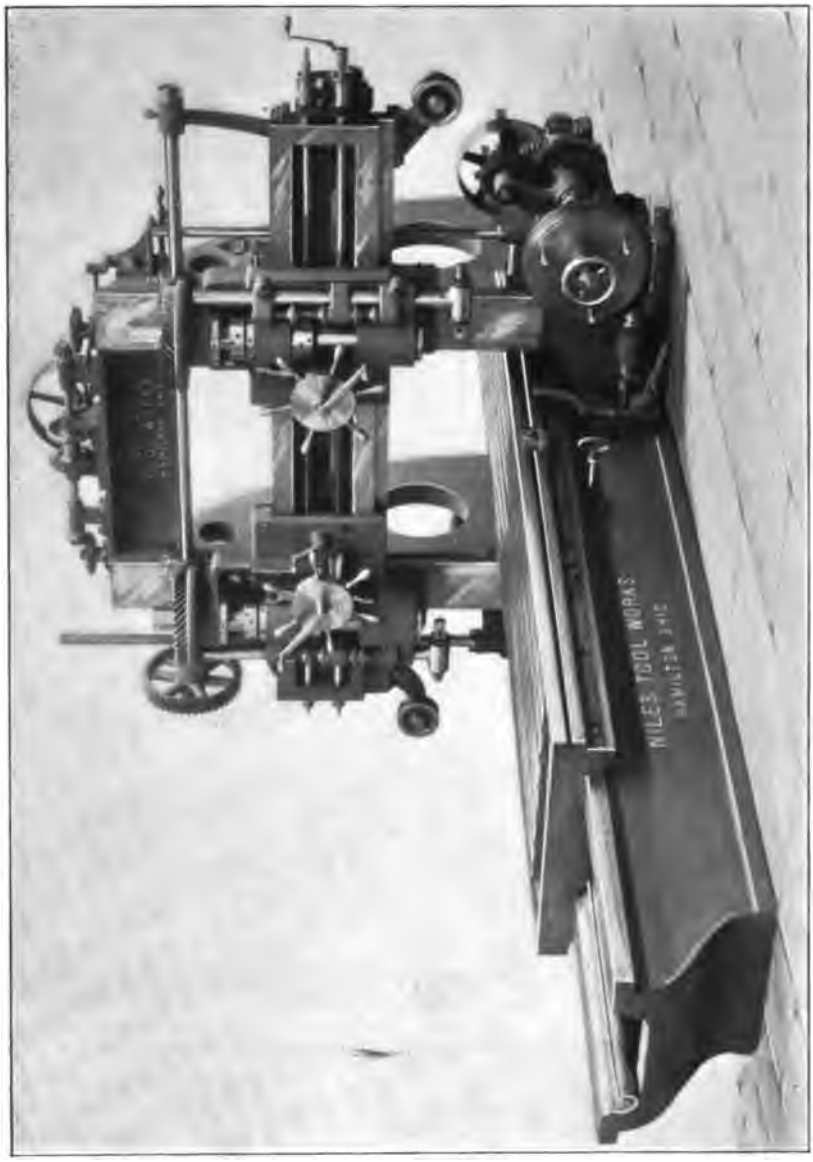


FIG. 5.—A PLANER TYPE MILLING MACHINE WITH TWO VERTICAL SPINDLES, MADE BY THE NILES TOOL WORKS COMPANY, HAMILTON, OHIO

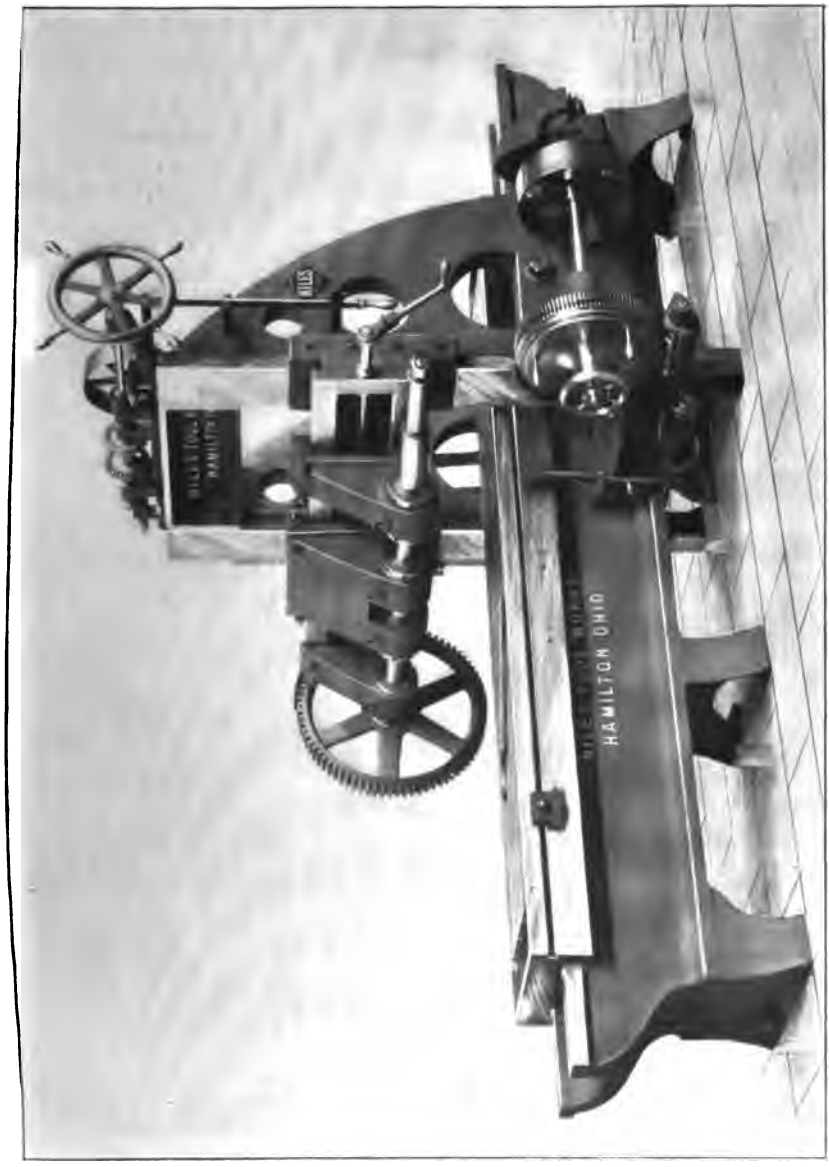


FIG. 6.—ANOTHER PLANER TYPE MILLING MACHINE WITH ONE HORIZONTAL SPINDLE. MADE BY THE NILES TOOL WORKS COMPANY. THIS IS A GOOD EXAMPLE OF WHAT ARE KNOWN AS SLAB MILLERS

the axial flutes of end-milling cutters. It is generally conceded that face milling is the more economical method of finishing surfaces, as compared with slabbing, and it is here that the vertical spindle miller has the advantage over the horizontal spindle machine, particularly in the manner of chucking the work. Let us consider the operation shown in Fig. 27. To accomplish this with a face mill on a horizontal spindle miller involves the use of a knee-plate fastened to the table of the machine, to secure a surface parallel with the face of the mill, for holding the work. That this is awkward is evident, and if the knee plate springs, as it is almost sure to do, it is impossible to get a true surface. To do the same job on a vertical spindle miller, the piece is simply clamped to the table of the machine, in doing which the operator is aided by gravity, and unless the machine itself should spring, there is no difficulty in getting a nicely finished, true surface.

When millers of this type are equipped with an auxiliary rotary table, as shown in Fig. 9, they are well adapted to finishing curved surfaces that end abruptly or merge into straight lines, and are especially valuable for finishing the periphery of circular pieces having irregular surfaces, as, for example, steam engine eccentrics. It is evident that by using a cutter of the proper form to give the outline desired, such pieces can be made exact duplicates of one another, and if the eccentric straps are finished in the same manner, with a cutter of the proper form, work can be produced that will be entirely interchangeable,—a result not so easily obtained on the lathe.

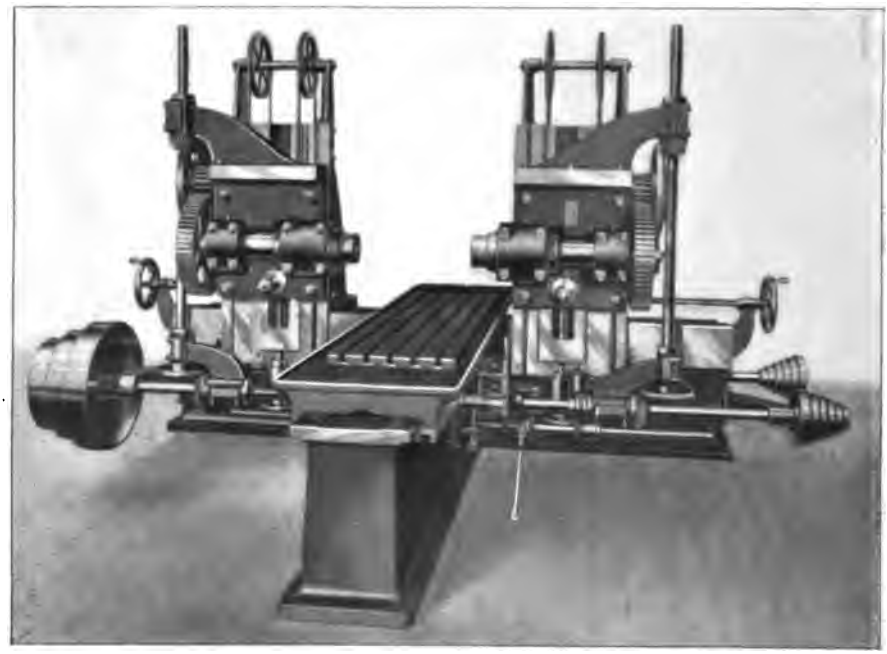


FIG. 7.—A DOUBLE-HEAD HORIZONTAL-SPINDLE MILLING MACHINE MADE BY THE PRATT & WHITNEY COMPANY, HARTFORD, CONN.

The Brown & Sharpe machine shown in Fig. 8, is especially interesting in the method employed for increasing the number and range of spindle speeds, and the feed-changing mechanisms. The spindle can be driven at twelve different speeds, six of which are ob-

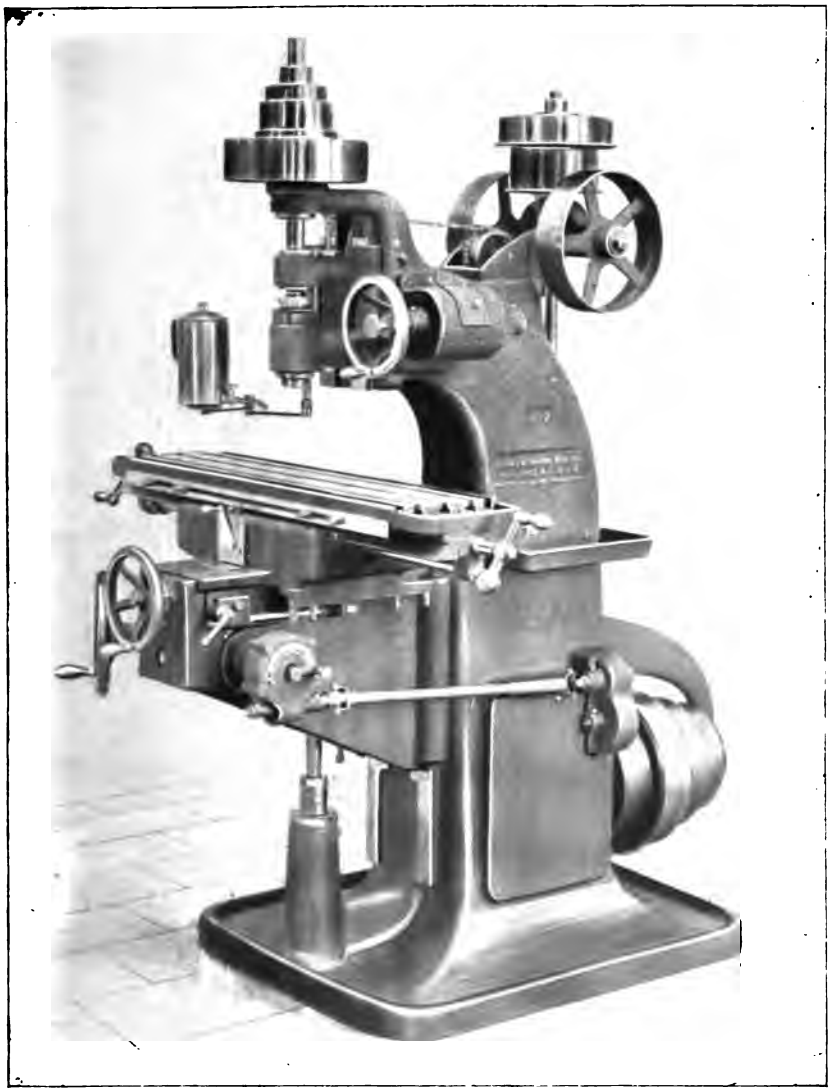


FIG. 8.—A COLUMN TYPE OF VERTICAL-SPINDLE MILLER, WITH GEAR-DRIVEN FEED MECHANISM BUILT BY THE BROWN & SHARPE MANUFACTURING COMPANY, PROVIDENCE, R. I.

ained through the usual medium of double countershaft pulleys in connection with the three-stepped cone pulley on the back of the machine, from which the speeds are transmitted to the spindle by the main driving belt which passes from the pulley on the cone shaft over the idlers at the top of the machine and drives the large pulley on the spindle. For each of these six speeds an additional faster speed is obtained through the use of two auxiliary belts, one of which runs on the large driving pulley, passing underneath the main driving belt which rides on it to the small step of the pulley on the vertical shaft at the rear of the machine, while the other runs from the large step of the pulley at the back of the machine and drives the small driving pulley. When the

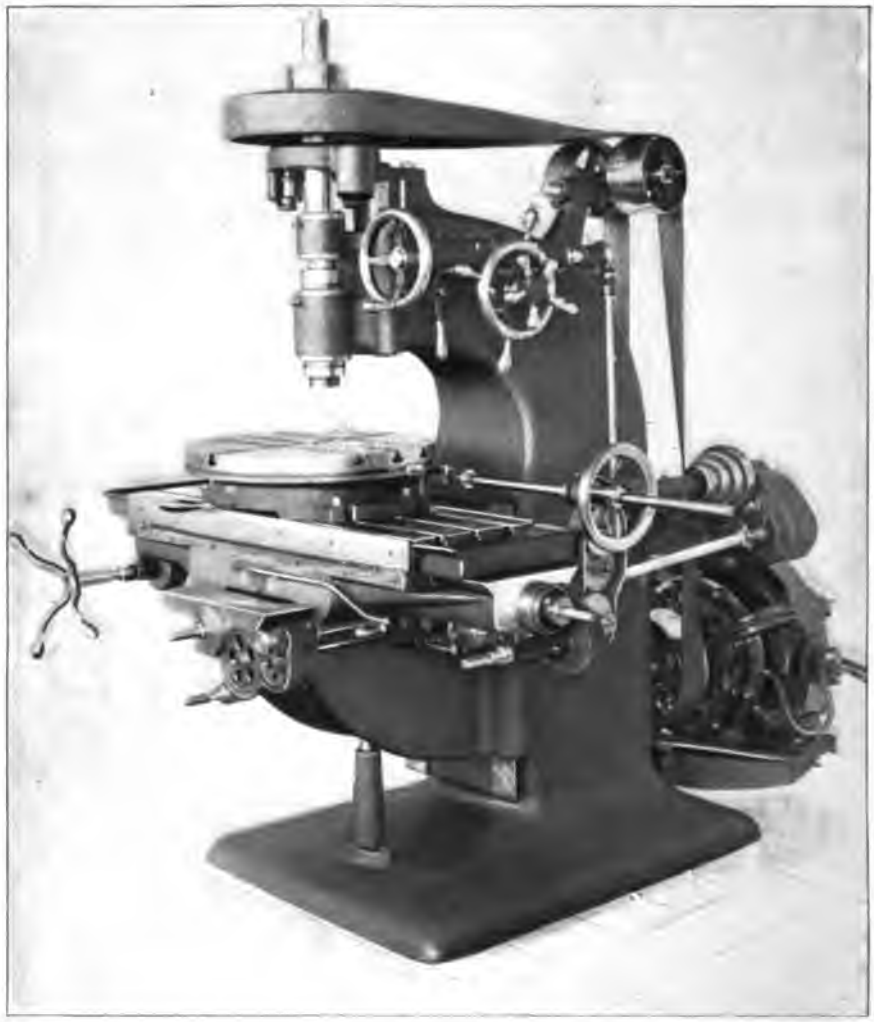


FIG. 9.—A HEAVY VERTICAL-SPINDLE MILLING MACHINE WITH AUXILIARY ROTARY TABLE AND ELECTRIC MOTOR DRIVE. MADE BY THE BECKER-BRAINARD MILLING MACHINE COMPANY, HYDE PARK, MASS.

spindle is driven at these higher speeds by the auxiliary belts, the large driving pulley is disconnected and runs free. On the other hand, when the spindle is being driven at the slower speeds, the top auxiliary belt must, of course, be taken off. The vertical shaft serves to drive the feed mechanism which is almost entirely enclosed in the column of the machine.

The feed changes are secured by a single lever movement, causing a sliding gear to be brought into mesh with the proper unit of the nest of gears of different diameters which forms the feed varying device. Motion is carried from this sliding gear to the table through spur gears and the usual universal joint shaft. Since the belt which drives the vertical shaft is of the same size as the main driving belt, being virtually the main driving belt when the higher speeds are used, it is evident that the feed of this machine is positive to the full extent of the meaning of that term as at present applied to machine tool feeds.

Fig. 9 illustrates a machine of the same type, made by the Becker-Brainard Milling Machine Company. This is shown with rotary table in position on the platen of the machine. The automatic power feed of the rotary table does not interfere in any way with the regular feed of the main table, which makes possible the successful milling of irregular surfaces mentioned above. The machine is fed through the medium of cone pulleys and belt. The cut shows the machine direct connected to a motor, the armature of this occupying the same position as the cone pulley on the machine shown in Fig. 9.

A heavy vertical-spindle miller having a bevel gear spindle drive, made by Messrs. Bement, Miles & Co., is shown in Fig. 11. The spindle has hand vertical adjustment, and is driven by a 4¼-inch belt on a four-step, 21-inch diameter cone, through the medium of bevel gears with a ratio of five to one. A circular work table, 32 inches in diameter, forms part of the machine, and it has power rotary, longitudinal, and transverse feeds, which can be varied infinitesimally while the machine is running, being driven by friction discs. Provision is made for the use of copying attachments.

Although the present tendency is toward the use of the heavier milling tools, there has been no abandonment of the smaller machines. On the contrary, as milling operations become more clearly understood, the field also widens for the small millers. The machine shown in Fig. 12, which is made by the Whitney Manufacturing Company, is supplied with a weight attachment which provides automatic vertical and horizontal feeds. The table is also provided with hand screw feed, for making long cuts, which obviously gives a smoother motion than the lever feed through rack and pinion and reduces the liability of cutters "gouging" into the work. These machines are excellent for taking short, rapid cuts, as when slitting small copper and brass work for electrical fittings, forming certain cash register details and other similar work that does not require a particularly high finish and which is of such a form as to be difficult to hold in string jigs.

The machine shown in Fig. 14 is made by the Pratt & Whitney Company, and the chief points of difference

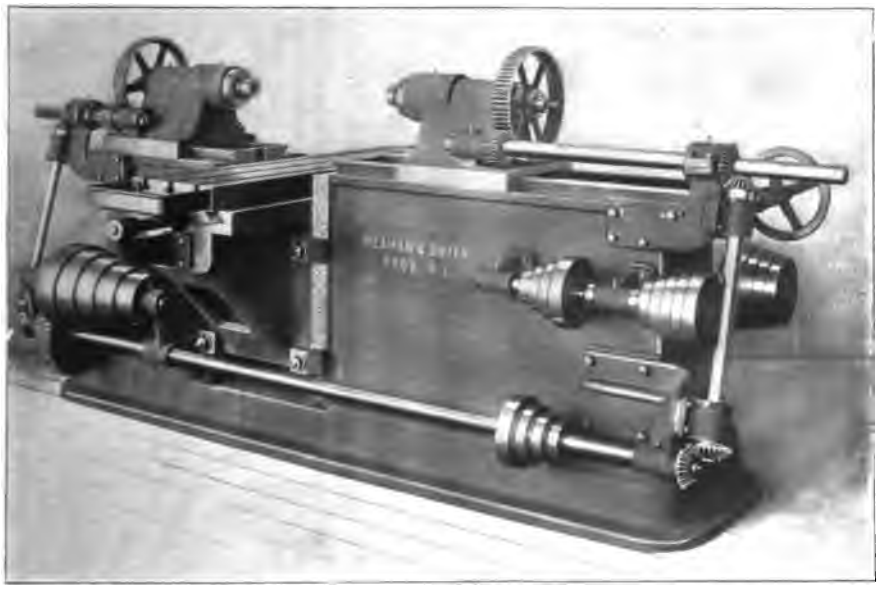


FIG. 10.—DUPLEX MILLING MACHINE BUILT BY THE BEAMAN & SMITH COMPANY, PROVIDENCE, R. I.

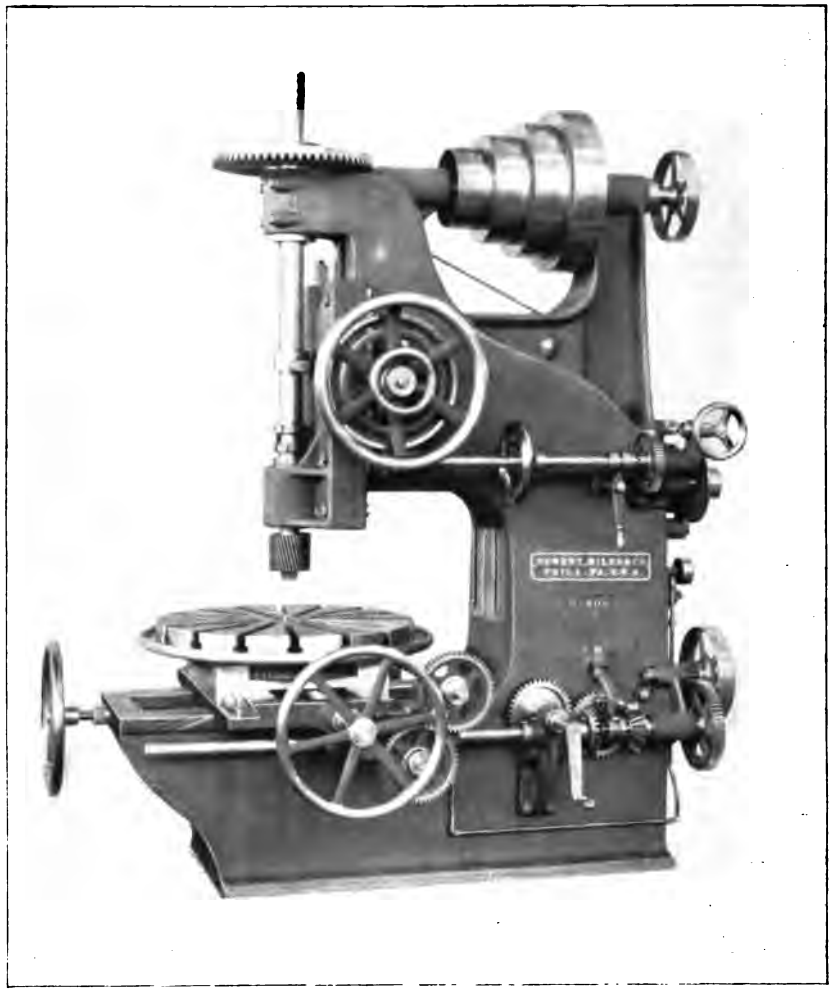


FIG. 11.—A HEAVY VERTICAL-SPINDLE MILLER MADE BY MESSRS. BEMENT, MILES & CO., PHILADELPHIA, PA.

between it and the machine in Fig. 12 are made evident by a comparison of the illustrations.

One of the oldest, and probably the best known, types of miller is the "column and knee" machine, which came into existence several years after the Lincoln miller first achieved success. The first departure from the conventional design of the Lincoln miller was made about 1854, when Mr. E. K. Root, who was then superintendent of the Colt Armory at Hartford, designed the miller illustrated in Fig. 15, which embodied all the essential features of the Lincoln type, except that in this machine the outer end of the arbour is carried by a support from an overhanging arm secured to the head of the machine instead of the usual outer support resting on the bed. This construction possessed the great advantage of being what in a planer is called "open side," capable of performing operations on work that could not be passed between the head and foot stock of the Lincoln miller. From this machine it is but a step to the early Garvin plain miller

shown in Fig. 13, which was designed several years later.

Contemporaneous with the latter was the invention of the "universal" milling machine by Mr. J. R Brown, who, about 1860, was confronted by the need of a machine that would produce spiral forms quickly and accurately in the manufacture of sewing machines. He constructed a milling machine having a swivelling table and equipped with an indexing and spiral generating device. These machines were put on the market in 1862. The first machine sold is illustrated in Fig. 16, and justly deserves the honour of being the first universal milling machine. The machine in Fig. 13 combines the "column and knee" of the Brown machine, Fig. 16, with the "overhanging arm" arbour support used by Root, and in it we find the prototype of the "column and knee" miller of the present day.

Improvements were made on these early machines from time to time, and about 1886 a machine was brought out by the Cincinnati Milling Machine Company which embodied many important improvements invented by Mr. Frederick Holz, the present president of the company. This machine is shown in Fig. 17. In the design of this machine especial attention was given to provision for accurate adjustment and convenience of manipulation. The adjusting levers were all provided with micrometer dials, which were first used on a miller by Mr. Holz about 1881, and the shaft for elevating was placed at an angle so that the elevating crank and the cross screw handle could be used simultaneously.

These may seem like small and unimportant details, but it will be noticed that they have been almost universally adopted by the builders of this type of miller, and the perfecting of just such details has been the chief factor in the development of the miller and have gained for it the important place which it occupies to day.

Since that time rapid strides have been made in the advancement of milling processes, and radical changes in the design of the machines followed as a consequence. Just as the early machines were the direct outcome of the designers' needs for such a tool, so, we may safely say, the re designing that they have undergone from time to time has been the direct outcome of the needs of the builders and the needs of their customers

A comparison of the early machines of this type alone with the machines into which they have developed gives one

FIG. 12.—A HAND MILLER WITH OVERHANGING ARM. MADE BY THE WHITNEY MANUFACTURING COMPANY, HARTFORD, CONN.

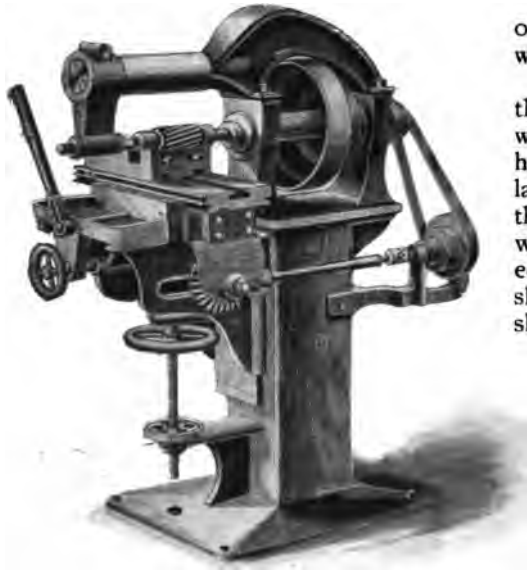


FIG. 13.—A "COLUMN AND KNEE" TYPE MILLING MACHINE OF FORTY YEARS AGO. MADE BY THE GARVIN MACHINE COMPANY, NEW YORK

an adequate idea of the growth of milling as a method of metal working. The early Brown miller was smaller than the smallest "universal" miller made to-day: it did not have a support for the outer end of the cutter arbour, and was intended only for very light work. It has developed into a series of universal millers, the largest of which has a table travel of 33½ inches and weighs approximately 4700 pounds.

The Holz miller of sixteen years ago was about the same size as the smallest plain millers of to-day. It had only six changes in speed for the spindle and only six changes in the rate of feed. The range of these speeds and the maximum rate of feed seem to have been considered of very little importance in those days, as they were not mentioned in the catalogues nor in the descriptions of the machines which appeared in the trade journals of the time. This machine developed into the plain miller shown in Fig. 25, which has a table feed of 42 inches, sixteen changes in spindle speeds and sixteen changes in rate of feed, ranging from 0.006 inch to 0.300 inch. The complete machine weighs approximately 4800 pounds.

The facility and accuracy with which these machines can be adjusted to the work, the ease with which they can be handled while in operation, and the large variety of attachments with which they can be equipped adapt them to a wide range of work and make them equally efficient for "jig" milling, slabbing, face milling, key seating, slotting, profiling, rack cutting, cam cutting, and gear cutting, and, if universal, we can also include the automatic generation and forming of helices, an operation which is especially useful in tool making, and in cutting the spiral gears which are being largely used in automobile and gas engine construction.

It is no wonder, then, that they have entirely replaced the Lincoln type millers, with the single exception of the armouries where a machine is set up and used for performing only one operation, in which case the

FIG. 14.—A HAND MILLER MADE BY THE PRATT & WHITNEY COMPANY, HARTFORD, CONN.

simply-constructed Lincoln miller is to be preferred. But for general manufacturing purposes, whether pieces are made singly or in lots, the knee type miller is the most convenient and efficient tool that can be used. These machines can be set up in a very short space of time to suit any job that comes within the range of their table travel, and are

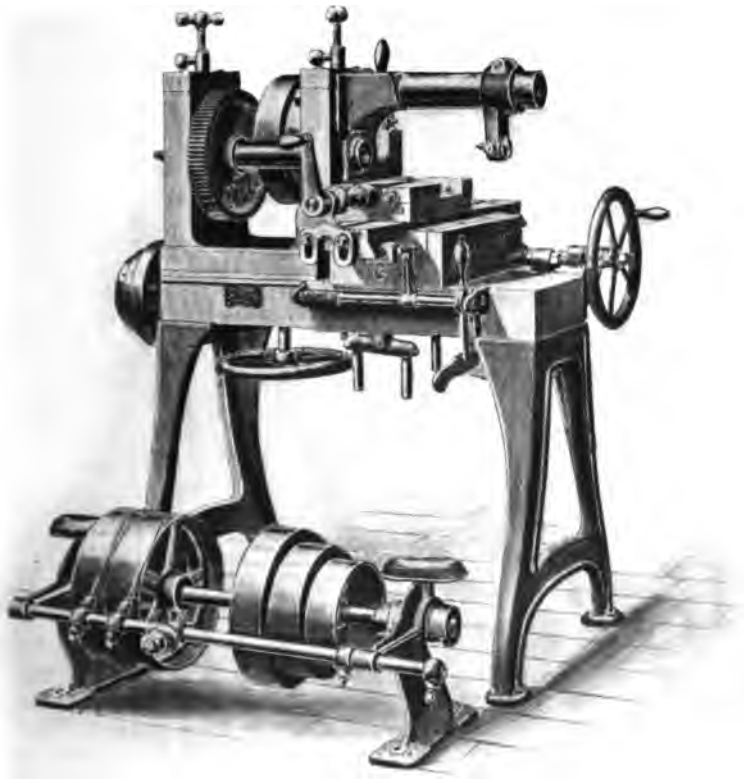


FIG. 15.—A ROOT MILLER OF HALF A CENTURY AGO

equally efficient for taking a long cut on a single piece, milling a row of pieces in a string jig, or for milling a single piece at a time when the surface to be finished is short.

The proper way to hold the work is, of course, by means of special fixtures. But this applies to the shaper, planer, and drill press, as well as to the milling machine. The modern manufacturing machine shop has as complete and expensive a jig equipment in its drilling and planing departments as in its milling department, and the economy of such an equipment is well recognised.

It is a rather common notion among shop men generally that work can be done economically on a miller only when the pieces are held in special fixtures. As a matter of fact, the table of a modern miller has a large working surface, and it is provided with a liberal number of "T" slots, so that work can be clamped as easily and as satisfactorily on it as on one of the older and better known tools.

Fig. 30 shows a "column and knee" type miller performing the operation of milling a gas engine bed for the crankshaft bearing, and it will be noticed that in this case the work is clamped to the

FIG. 16.—THE FIRST UNIVERSAL MILLING MACHINE. MADE BY J. R. BROWN & SHARPE IN 1867

table of the miller with such common appliances as are used on the simplest tools. That these machines are being used for very heavy work,—that is, deep and coarse feeds,—is evidenced by the fact that the old method of driving the feed screws by means of a belt is being rapidly replaced by positively driven feeding devices, either entirely through gearing, as in the machines shown in Figs. 9, 18 and 25, or by a combination of gears and chain, of which Fig. 19 shows a good example.

The machine shown in Fig. 18 is a direct development of the first Cincinnati miller, shown in Fig. 17, and is a good example of the "geared feed" machines made by that company. One of these machines was exhibited at the Paris Exposition in 1900, and was the first universal milling machine which embodied the combination of a positive feed drive and a quick feed changing mechanism. These features were very much commented upon, and not always favourably, because even at that recent date a great many well-known machine tool men feared the consequences that might result from accidents on a miller that did not possess the "safety valve" of a slipping feed belt. Hardly two years have passed since then, yet so complete has been the reversal of opinion that 1902 is seeing the almost universal adoption of some mechanism designed to form this combination on millers of this type. Faster feeds are being used than were considered practicable several years ago, when a feed of 0.150 inch per revolution of cutter was thought to be excessive.

The machine in Fig. 18 provides six-

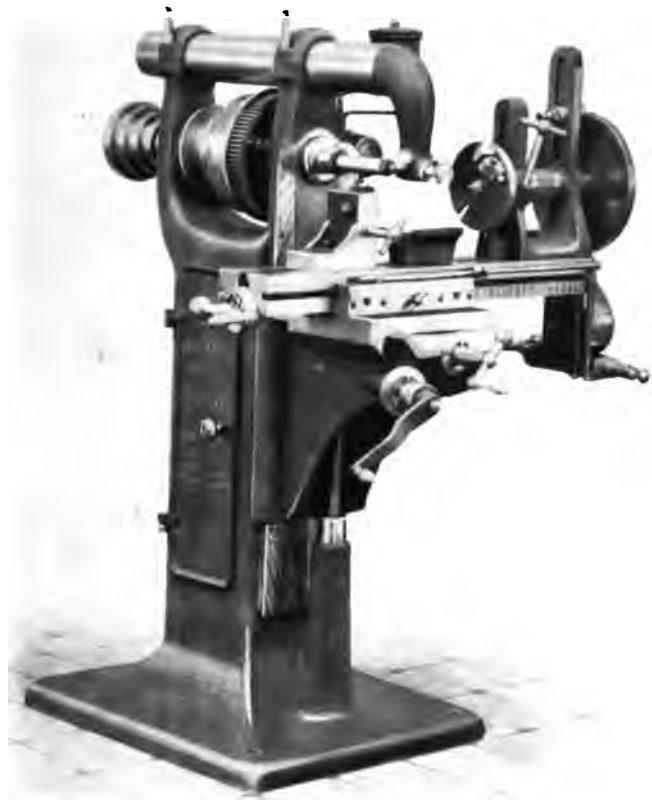


FIG. 17.—FREDERICK HOLZ'S MILLER OF 1886. MADE BY THE CINCINNATI MILLING MACHINE COMPANY, CINCINNATI, OHIO

teen changes of feed, ranging from 0.006 inch to 0.300 inch per revolution of cutter, and this particular feed-changing device permits changing the rate of feed through the whole series of changes while the machine is working. This is accomplished by bringing the different combinations of gears, formed by a fixed cone of gears and a sliding gear, into mesh radially by a simple movement of the levers shown over the feed-box at the rear of the machine, and the rate of feed is at all times indexed by the position of the lower lever.

It has power feed for the table in all directions, namely, lengthwise of the table, crosswise in line with the spindle, and vertically, the feed in all directions being under control of a reversing lever. The method of swivelling the table is the same in principle on all universal millers, and provides sufficient angularity to cut spirals up to and including 45 degrees.

Fig. 19 shows a machine brought out recently by the Brown & Sharpe Manufacturing Company. This is entirely new in design and embodies some very interesting features. The overarm is clamped by a single lever attached to one of the clamping bolts. Each of the clamping bolts carries a pinion, and both engage rack teeth cut in a bar which connects the bolts, so that they are both operated simultaneously.

The feeding mechanism is positive in its action, being driven from the main spindle of the machine by a chain to a

sprocket which can be clutched to either one of two prime driving gears of different diameters, the clutches being operated by the small lever which can be seen on top of the gear-box. Power is transmitted from either one of these prime drivers to an intermediate shaft carrying two sets of gears, three gears of different diameters in each set, and all keyed to the shaft. These six gears drive a series of six loose gears, all of which run independent of one another, on a shaft that is connected directly to the knuckle joint shaft which transmits motion to the clutches driving the feed screws. These six pairs of gears are always engaged, and the variation of feeds is obtained by engaging the different members of the series of loose gears with the shaft on which they run. This is accomplished through the medium of a series of six locking pins, carried in a ring keyed to the shaft, and so arranged as to engage the different gears in the series, recesses being provided in the hubs of the gears to receive them. The pins are controlled by a cam, carried by an index disk.

FIG. 18.—UNIVERSAL MILLING MACHINE WITH GEARED FEED MECHANISM, MADE BY THE CINCINNATI MILLING MACHINE COMPANY, CINCINNATI, OHIO

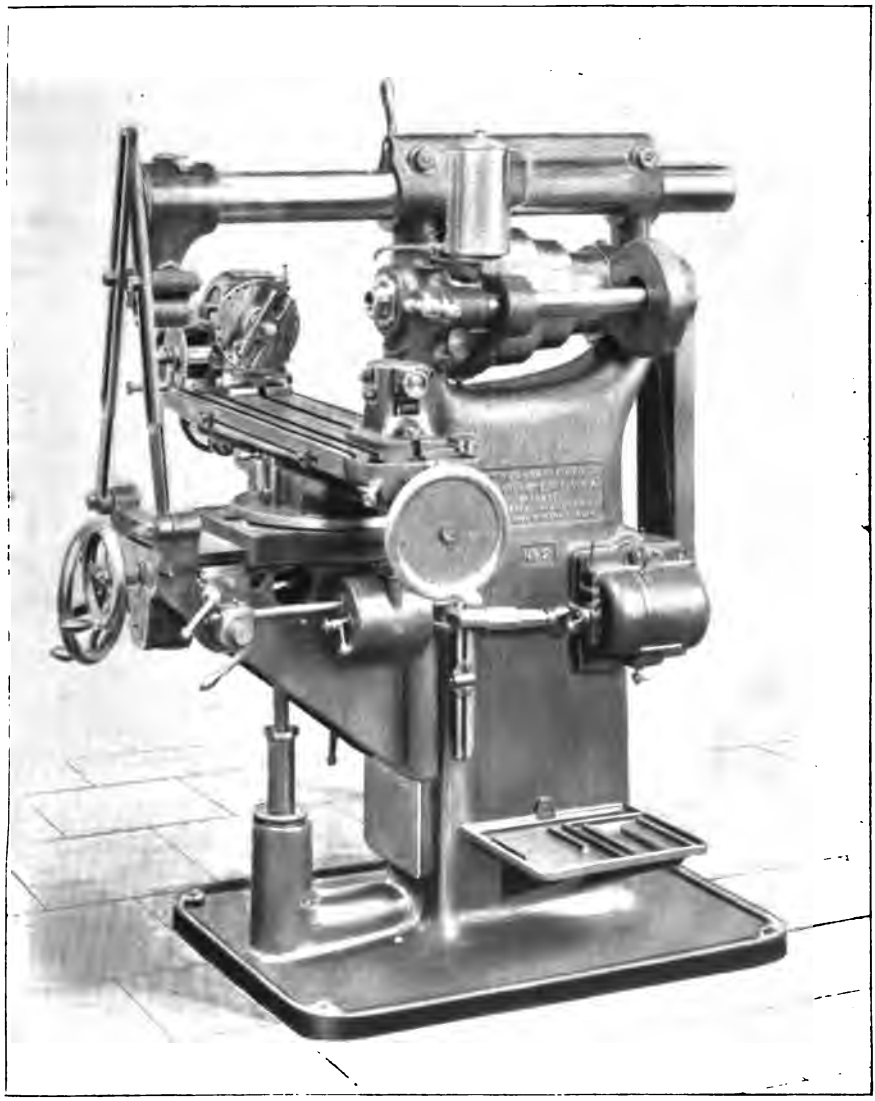


FIG. 19.—A UNIVERSAL MILLER WITH POSITIVE FEED DRIVE, MADE BY THE BROWN & SHARPE MANUFACTURING COMPANY, PROVIDENCE, R. I.

and arranged in such a manner that there is no possibility of engaging more than one feed at a time. The index disk is figured to correspond to the feed table on the outside of the case, and the change from one rate of feed to another can be made in a very short time.

The six pairs of gears described provide as many changes in feed, and this number is doubled by the two prime drivers, making a total of twelve feed changes, ranging from 0.005 inch to 0.100 inch per turn of cutter. All feeds are reversed by a lever that can be plainly seen on the case which contains the reversing mechanism, and is mounted on the side of the knee. The main spindle is driven by a three-speed countershaft which, in connection with the three-stepped driving cone and back

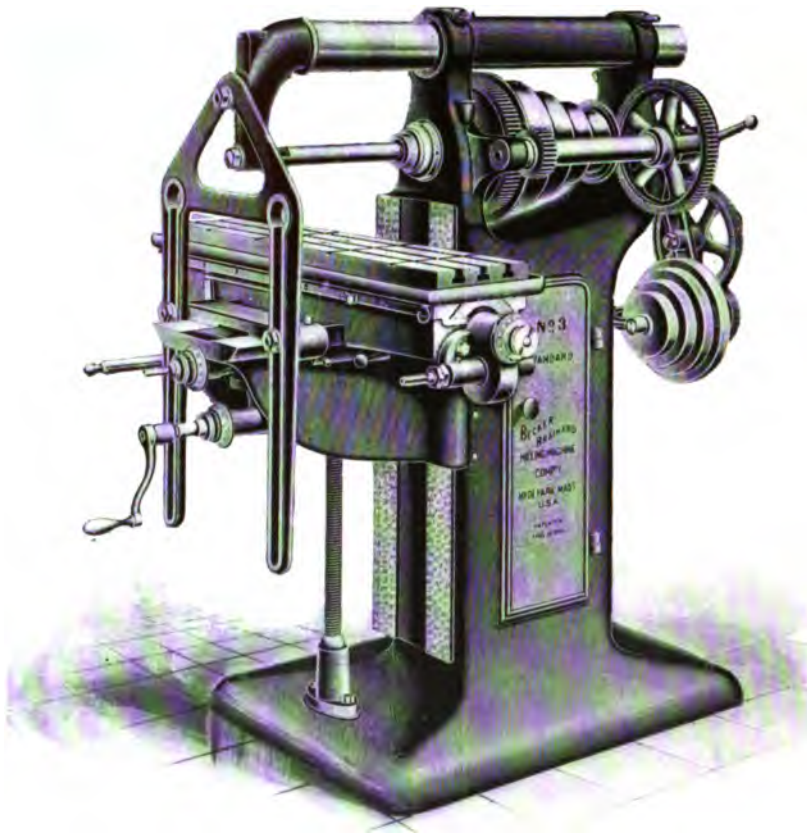


FIG. 20.—A PLAIN MILLER MADE BY THE BECKER-BRAINARD MILLING MACHINE COMPANY, HYDE PARK, MASS.

gears, provides twelve speeds in "forward" direction and six reverse, the "forward" speeds ranging from 18 to 366 turns per minute.

A universal miller with belt-driven feed, having a lever feed changing device, is illustrated in Fig. 21. This is one of a series of millers made by Kearney & Trecker. The levers, by the simple movement of which any one of twelve changes in feed can be obtained, are clearly shown on the feed-box at the rear of the machine.

In Fig. 20 is shown a plain miller made by the Becker-Brainard Milling Machine Company. It has a belt-driven feed, changes being secured by the use of stepped cones and change gears. A distinctive feature of this machine is the extreme length of its saddle, which forms a bearing for the table as long as the table itself.

Another universal miller with belt-driven feed is shown in Fig. 22. This illustrates the present style of machines made by the Kempsmith Manufacturing Company, which have grown out of the original designs made by Mr. Frank Kempsmith, who was closely identified with the development of the modern universal miller, and to whom belongs the credit of having first recognised the value of, and used, a tie between the tops of the column carrying the spindle bearings in machines having a horizontally adjustable overhanging arm.

These machines first appeared about 1890, and within a few years thereafter the top tie was placed on nearly all machines of this type. The spindle of this machine is driven by a four-step cone from a two speed countershaft; being back geared, it has sixteen changes in speed. The feed is driven through a four-speed gear train and a belt running on a four-step cone, giving sixteen changes in the rate of feed, ranging from 0.004 inch to 0.100 inch per turn of spindle. The four changes provided by the gear train are under the control of a lever, and changes can be made without removing any parts. The feed of the table is automatic in all directions, that is, longitudinal, crosswise, and vertical.

The universal miller shown in Fig. 24 is a newcomer in the field, which will gain for itself an important place in competition with other makes. It is made by the Hendey Machine Company, and is equipped with the well-known Norton feed changing device, providing eighteen changes in the rate of feed, ranging from 0.003 inch to 0.160 inch per revolution of cutter. The feeding mechanism is contained in the column of the machine, and is driven from the main spindle by a belt. This machine possesses a telescopic elevating screw, an upturned rim on

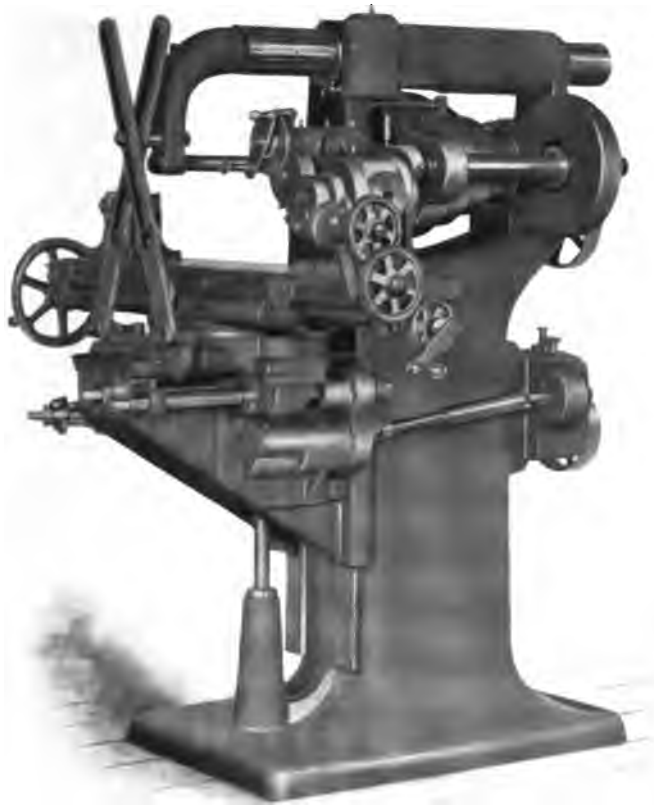


FIG. 21.—A UNIVERSAL MILLING MACHINE MADE BY MESSRS. KEARNEY & TRECKER, MILWAUKEE, WIS.

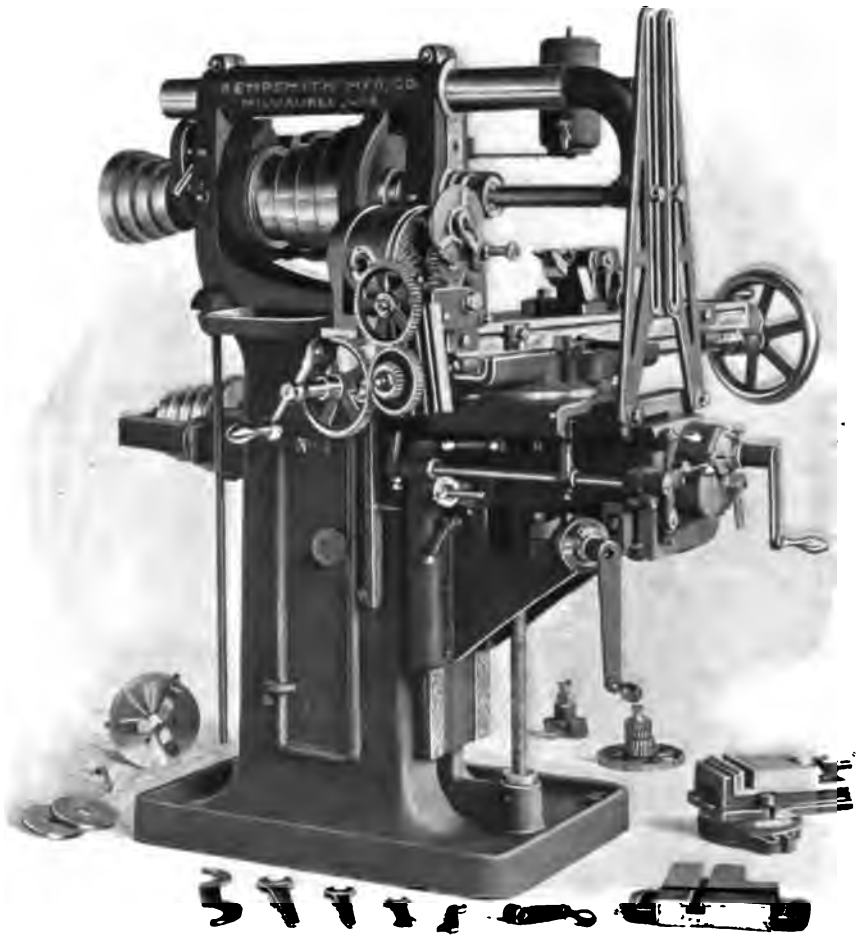


FIG. 22.— UNIVERSAL MILLING MACHINE WITH BELT-DRIVEN FEEDS IN ALL DIRECTIONS. MADE BY THE KEMPSMITH MANUFACTURING COMPANY, MILWAUKEE, WIS.

the base, which forms a catch basin, lever clamps for locking the knee, column and saddle together, and the angular position of the elevating shaft, all of which are common to the other machines of this type.

A series of plain millers which embody the same general design as the universal miller in Fig. 18 is made by the Cincinnati Milling Machine Company, the largest of which is illustrated in Fig. 25. This machine is intended for a heavy class of work, and is shown in operation in Figs. 23, 28 and 30.

Each one of the machines illustrated in this article is a good example of the particular type of machine which it represents. No attempt has been made to show examples of all makes of machines, and in the final selection of the examples shown many good makes were omitted for want of space.

The types illustrated cover the entire field of American milling machine construction, using the term in its restricted sense, exclusive of those machines which are designed for performing a single operation, such as automatic gear cutters, cold saw cutting-off machines, worm and worm-wheel forming ma-

chines, rotary planers, etc., and an idea of the extent to which this one special branch of the machine tool industry has grown can be gained from a consideration of the fact that there are to-day more than thirty different machine tool builders in the United States who make milling machines, and six of this number manufacture millers exclusively.

Until quite recently the milling machine was supposed to be adapted to finishing only very small, light work. The extensive use of the large planer type machines, however, has demonstrated the practicability and economy of milling the heaviest pieces.

The chief difficulties that have barred the progress of milling operations in the past are:—

1.—Improperly constructed cutters.
2.—Inadequate rigidity of machine.
3.—Timidity due to lack of experience on the part of both builders and operators.

The most common defect in cutters is the lack of sufficient space for chips between the cutting edges. Early milling cutters had very small teeth, resembling somewhat the teeth of a file, and their action, as compared with the action of a modern milling cutter, was more of a grinding than a cutting process. But with the development of the milling machine came improved cutters, and as the machines were made stronger and more rigid cutters of larger size, having larger teeth with wide spaces between them, were introduced. Good examples of modern cutters are shown in the illustrations of milling operations, —Figs. 23, 26, 27, 30, and 31.

The little illustration on the opening page of this article shows a heavy cutter with spiral, nicked teeth, and represents a style of cutter that is very efficient for taking roughing cuts. It is 4½ inches in diameter, has twenty teeth, 1 1-16-inch pitch, which leaves ample space between the teeth for chips. The nicks in the cutting edges of the teeth give the cutter a free cutting action and reduce the tendency to chatter to a minimum, producing short chips, of which

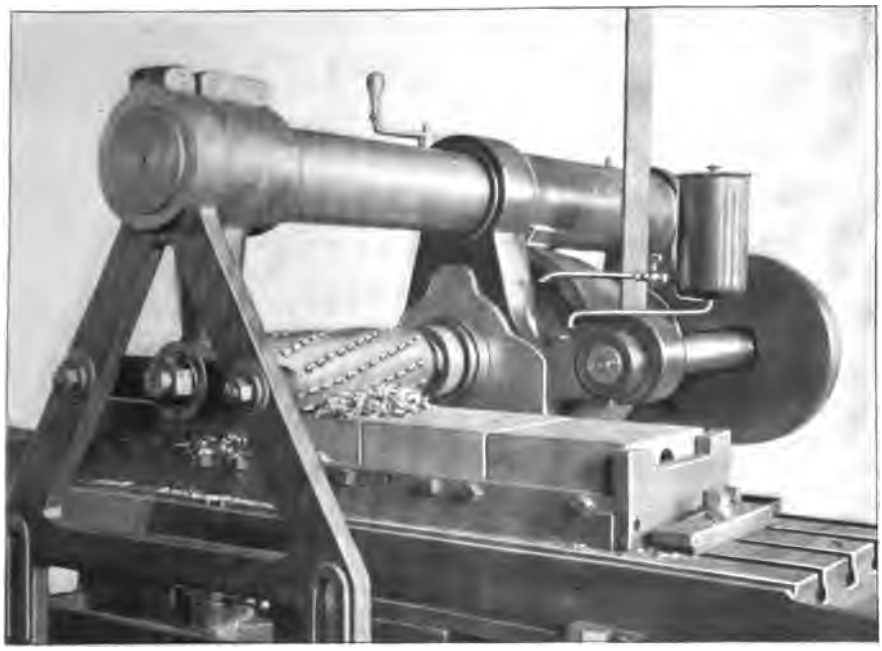


FIG. 23.—ROUGHING OFF CAST-IRON WITH AN INGERSOLL DRILL ON A CINCINNATI PLAIN MILLER, FEEDING 8½ INCHES PER MINUTE

the cutter easily clears itself. When a cutter with closely spaced teeth is used for taking a heavy cut, the spaces between the teeth become clogged with chips and the cutting edges are dulled as much by being obliged to recut these chips as by actually removing metal from the surface being milled.

These difficulties were obviated to a great degree by the invention of the Ingersoll milling cutter (see Fig. 23), which consists of a cast-iron cylinder into which are drilled a series of radial holes, laid out in the form of a spiral. Into these pieces of tool steel are driven, and their projecting ends form the blades or teeth. It is plain that such a cutter will clear itself of chips, and it is considered good practice to rough off cast iron with a feed of from 6 to 10 inches per minute with an Ingersoll mill 4½

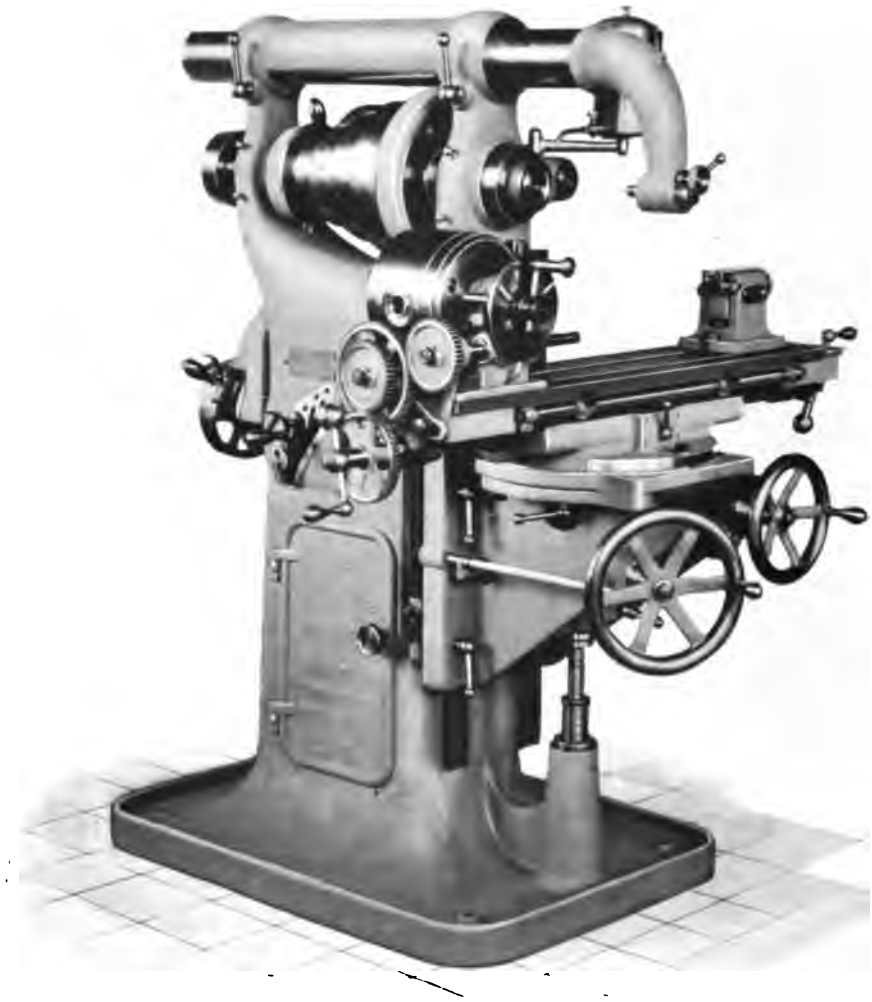


FIG. 24.—A UNIVERSAL MILLER MADE BY THE HENDEY MACHINE COMPANY, TORRINGTON, CONN.

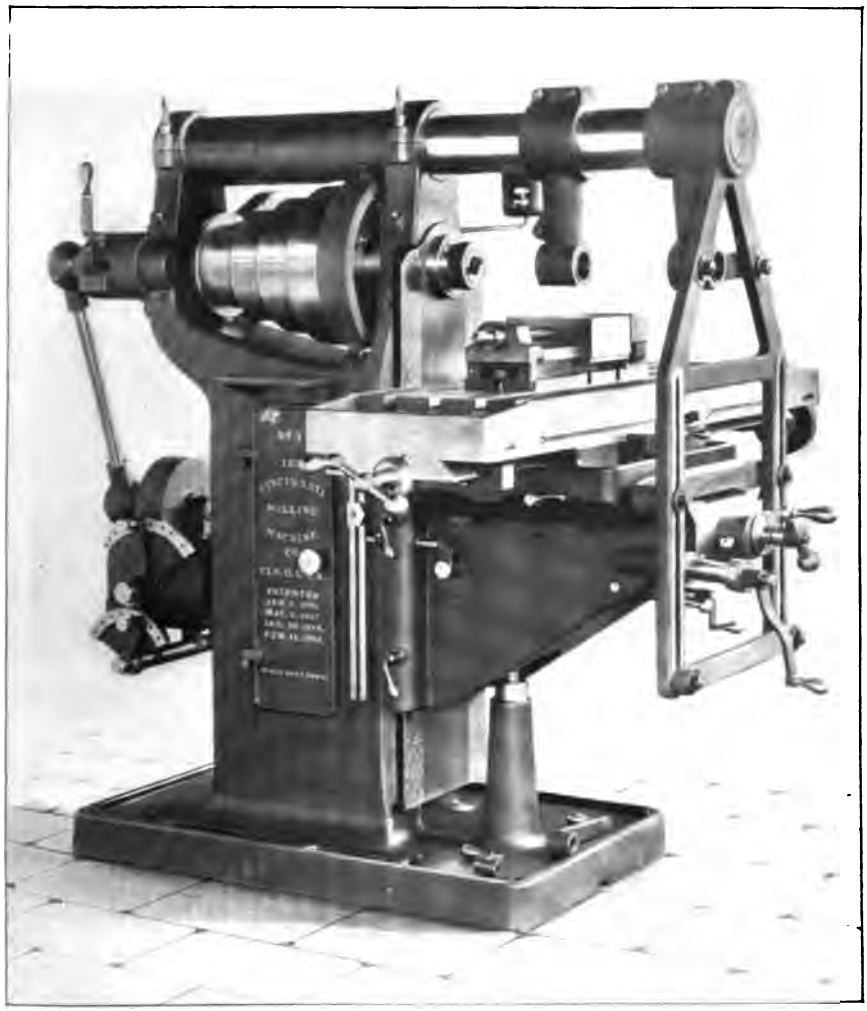


FIG. 25.—A HEAVY PLAIN MILLER WITH GEARED FEED MECHANISM, MADE BY THE CINCINNATI MILLING MACHINE COMPANY, CINCINNATI, OHIO

inches in diameter. In performing the operation shown in Fig. 23, the machine was feeding 8½ inches per minute, taking a roughing cut ⅛ inch deep and 8¼ inches wide in cast iron, with an Ingersoll mill, 4½ inches in diameter, working at a surface speed of 40 feet per minute.

Fig. 28 shows the same machine finishing irregular surfaces to gauge by using cutters in gangs. The material is cast iron, and the piece is held in a jig and finished in two operations, using two sets of cutters. The first operation consists of a roughing cut, and when it is complete, the arbour carrying the roughing cutters is replaced by an arbour carrying a set of finishing cutters. The piece is very frail, and for that reason is difficult to mill, making two cuts necessary, and even then the machine must be fed very slowly. The cutters are 3×6 inches in diameter, and the roughing cut is taken with a feed of 0.052 inch per revolution of cutter, the cutters making

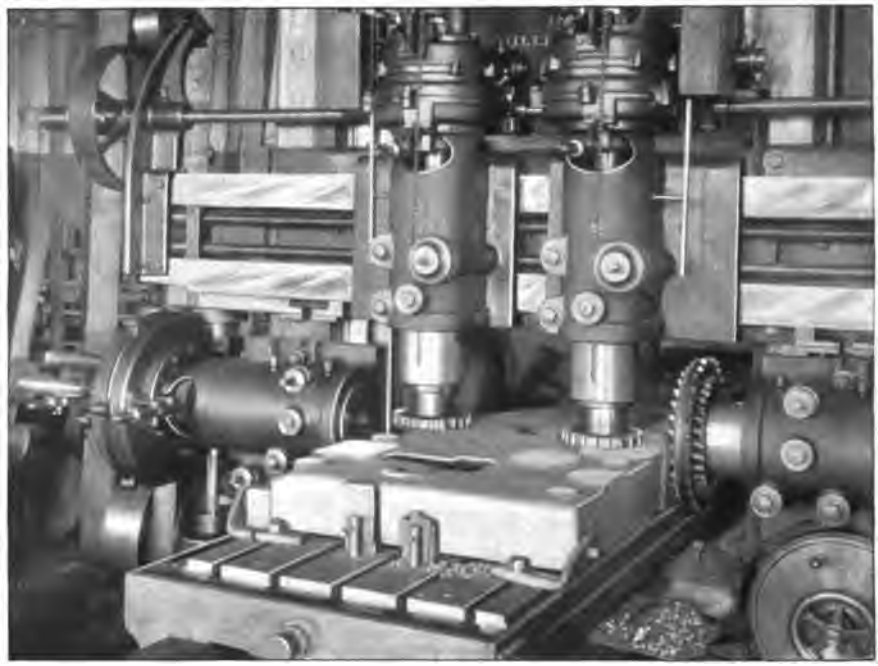


FIG. 26.—FOUR-SPINDLE INGERSOLL MILLER FINISHING SEVERAL SURFACES AT ONE OPERATION

26 revolutions per minute, while for the finishing cut the rate of feed remains the same and the speed of the cutters is increased to 40 revolutions per minute. This job is being done in the manner described in just one-half the time required to do it on a planer when using the same jig, and is finished with a greater degree of accuracy.

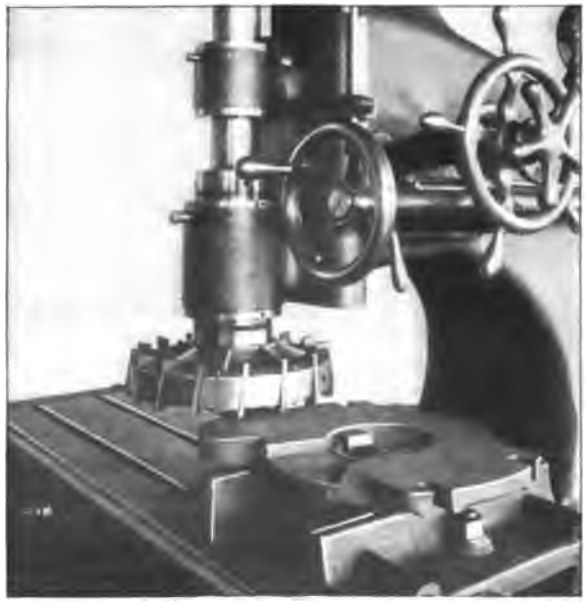


FIG. 27.—FACE MILLING ON A BECKER VERTICAL MILLER

Fig. 26 shows a four-spindle Ingersoll miller finishing two sides of an iron casting at one operation. The cutters are worked at a surface speed of 35 feet per minute, and the table travels at an average of 3 inches per minute, requiring less than one-half the time required to do the same work on a planer. It is, of course, evident that this machine can finish three sides of the casting at one time if desired.

Figs. 27 and 31 show a

Becker vertical-spindle miller in operation, the first being an example of face milling, with an economy over the planer of three to one, and the second, milling spots on an inside surface with an end mill, giving an economy over counterboring of ten to one. Both these are examples of work that would be difficult to hold for face milling with a cutter in a horizontal spindle.

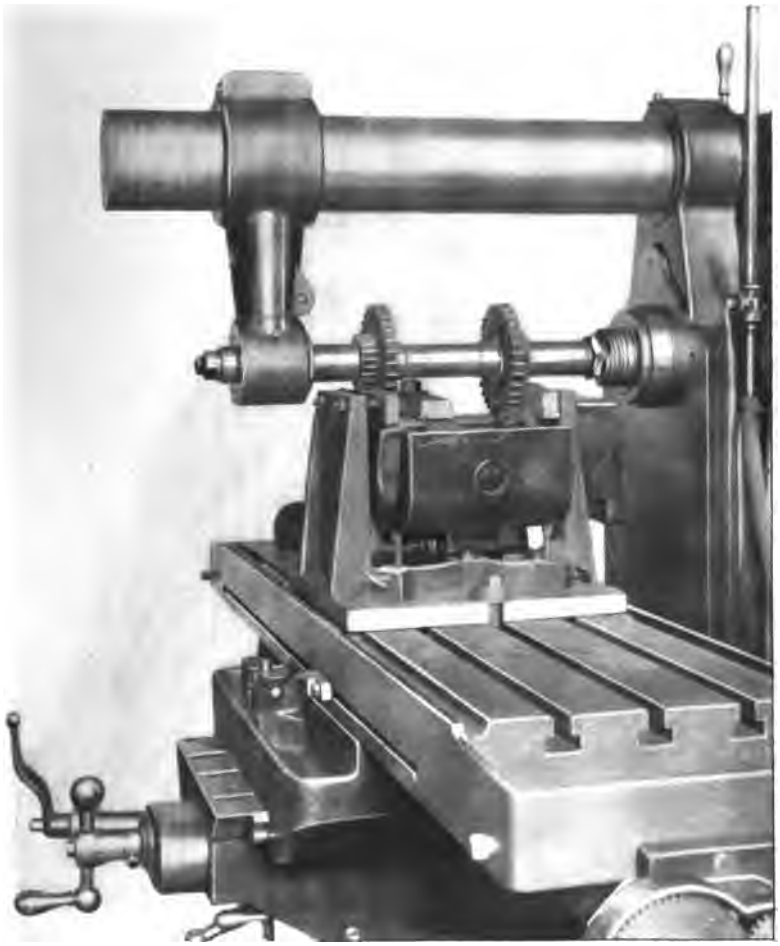


FIG. 28.—"GANG" MILLING WORK TO GAUGE

Fig. 29 illustrates the operation of cutting a number of spiral gears at one time on a Milwaukee universal miller. The gears are held on a mandrel which is supported at its outer end by an adjustable cylindrical bearing instead of the usual pivot bearing of the tail stock centre. The arrangement shown is only temporary, being classed as a special fixture for that particular job; but the advantage of a cylindrical bearing in this place, when milling heavy work, is so obvious as to make it surprising that it is not generally used.

In Fig. 30 a method is shown of finishing gas engine frames at the bearing for the crankshaft boxes. The work is clamped to the table of the miller without the use of any special fixtures, just as they had

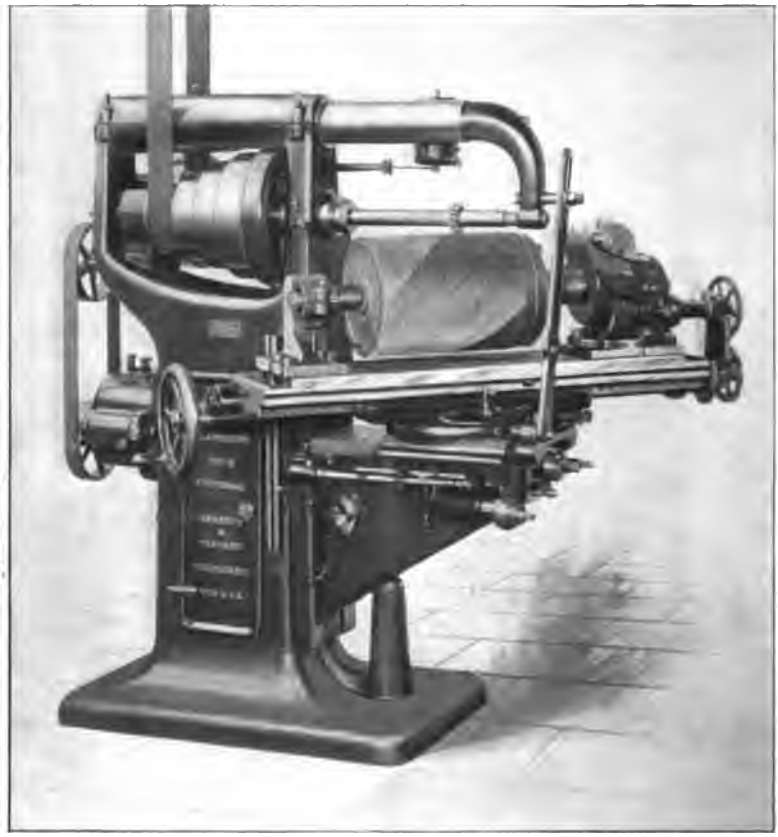


FIG. 29.—MILLING SPIRAL GEARS ON A KEARNEY & TRECKER UNIVERSAL MILLING MACHINE

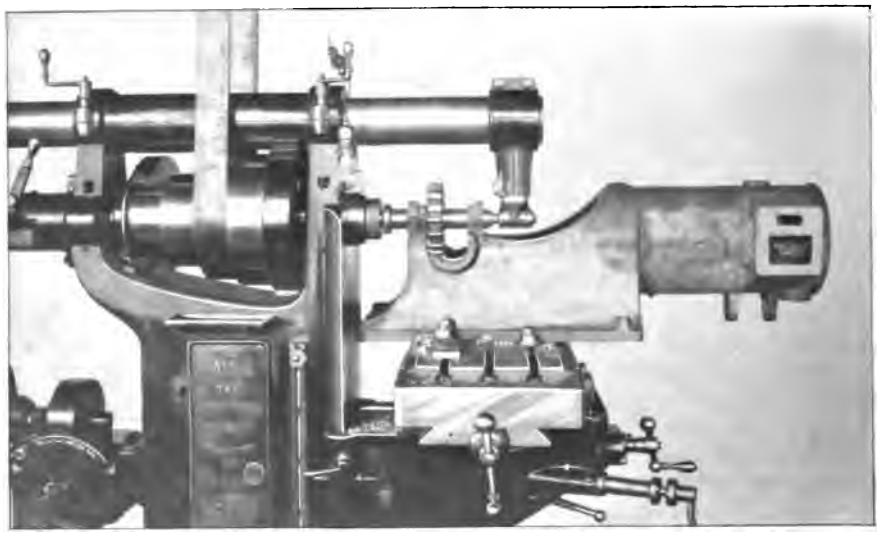


FIG. 30.—MILLING ENGINE BEDS ON A CINCINNATI PLAIN MILLER

formerly clamped it to the platen of a planer. The table is fed 1¾ inches per minute when the cutters enter and leave the cut, and 1⅜ inches per minute through the heavy part of the cut. The average time consumed between picking the frame off the floor and replacing it, when finished, is given as "exactly twenty-eight minutes," while the time required to do exactly the same work, under exactly similar conditions, but on a planer, is given as "just one hour and thirty-five minutes."

The cost of the gang of cutters used on this work was approximately $50,—certainly a very small outlay when compared with the saving effected. The miller was handled by a 12½-cent boy, while "the planer was in charge of an expert planer hand, put on his metal to do the work in the shortest possible time," which shows an additional advantage in favour of the miller in this particular case, although it is questionable whether it is not better in the long run to put a competent, intelligent man in charge of a miller, for the same reason that one would put such a man in charge of a planer to do the same work.

The question is often asked, "What rule is there for determining the proper speed of cutters and the best rate of feed?" And when a direct answer is not forthcoming the questioner is at once disappointed, if not discouraged. As a matter of fact, no "hard-and-fast" rule can be given. The surface speed of the cutters for each job must be determined by the hardness of the metal operated upon. Forty feet per minute may be taken as a good basis for cast iron when taking a heavy roughing cut. For a light finishing cut, after the scale has been removed, 50 feet per minute is none too fast on ordinary machinery castings. In the same way 20 feet and 60 feet per minute are good base figures for determining the correct cutter speed when working tool steel and brass, respectively. Aside from the hardness of the material, the nature of the cut is also an important factor in determining cutter speeds. For instance, a slitting saw can be run about twice as fast as a large surface mill working on the same material.

FIG. 31.—FINISHING SPOTS WITH A BECKER VERTICAL MILLER

With regard to the rate of feed, the most advanced practice is to take a roughing cut with the fastest feed the machine will pull, providing the cutter used is strong in comparison with the machine, and even if the nature of the work requires a cutter of such a form as to be comparatively weak, it is considered better economy to break an occasional cutter than to allow the machines to work at a slow rate of feed.

When crowding a machine on cast iron work, a jet of air, delivered to the

cutter with sufficient force to clear away the chips as fast as they are made, permits the use of much faster feeds and prolongs the life of the cutter. A stream of oil has the same effect when working steel, and too great stress cannot be laid on the importance of delivering the oil under pressure, so as to wash the cutter entirely clear of chips.

The danger of burning the cutters lies in too fast a speed, not in too fast a feed, and when both speed and feed are up to the highest safe limit the actual rate of table travel per minute can often be still farther increased by reducing the speed of the cutter and increasing the rate of feed.

When taking a finishing cut the rate of feed must be determined entirely by the quality of finish wanted. A feed of 0.030 inch per turn of a 3½-inch diameter cutter when surface milling leaves a good finish, requiring very little scraping to give an excellent bearing surface for machine tool work.

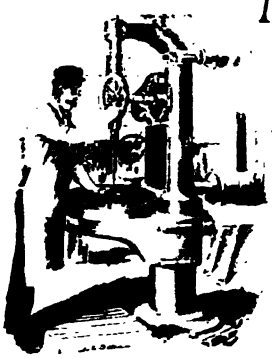
One of the most important factors upon which successful milling depends, and one that is so often overlooked, is that of properly sharpened cutters; consequently, a good cutter grinder is an indispensable adjunct to the milling machine.

The examples of milling operations given in this article have been selected not because they necessarily represent the best attainable results in milling, but rather to give an idea of what is current practice in milling work of widely varying character.

LIMIT GAUGES IN THE WORKSHOP

THE TRUE METHOD OF PRODUCING INTERCHANGEABLE WORK

By W. H. Booth



MEN who have been brought up to do mechanical work by the aid of fine gauges and machine tools cannot bring themselves to believe that good work can be produced by any other system. But it is quite erroneous to suppose that good work is not and has not been done with the most primitive of tools and skilled workmen.

In the writer's apprentice days heavy engine fly-wheels, from 20 to 30 feet in diameter, were entirely fitted up by hand. The only machine work on a fly-wheel was the boring out and facing of the holes in the boss to receive the arms, and the turning of one end of the arms to fit the boss. The rough spider thus built up was then handed over in pieces to the fitters, who first keyed the arms securely into their places, and, upon the arm ends, fitted the ten separate segments of the fly-wheel rim, while upon this rim were next fitted the ten toothed segments of the gear. The only tools employed were the hammer, chisel, and file, a bit of sheet-iron, and a chalked board as a gauge table. With these simple appliances the wheel was so fitted up that its face and one side ran true, which is more than can be said for any steam-engine fly-wheel I have yet seen imported into Great Britain from abroad and supposed to be made by the best modern machine tools on modern methods. If we did not do our fitting work to this excellence it was not that we heard of it from the foreman so much as the laugh among our fellow workers that put us to shame.

This is not put forward as a plea for old methods, but to point out that good men could do good work with poor outfits, and that it is a thoroughly mistaken idea that shops which are fifty years behind in equipment must, of necessity, turn out poor work. It may be poor in the sense that it is not interchangeable, but it will be sound and durable, and will work well.

The engineering work of Great Britain was practically founded by Watt upon the beam engine. Every part of this machine demanded skill. The beam was never a perfectly straight casting to begin with, but had to be lined up, and each of the various end gudgeons, air-pump gudgeons, feed-pump gudgeons, and the centre gudgeon had to be suitably turned and driven in to a proper depth to correct the lateral camber of the beam. The parallel motion work had to be accurately adjusted and the whole machine made to harmonise with a foundation of varying heights of heavy ashlar.

Needless to say, mechanical work was very expensive. No one can for a moment pretend that parts were interchangeable, though they were in many cases made fairly accurately to rod gauges, and turners were very skilful in using calipers on the gauge and on the piece turned, and the manner in which a workman would turn a rough cast-iron fly-wheel arm to be a tight keying fit in the bored boss was a very striking ex-

hibtion of skill. The object of modern systems must be to secure good and interchangeable work at a fraction of the expense incurred by the

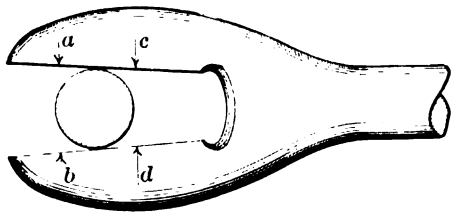


FIG. 1

old methods. Modern methods also have enabled different constructions to be adopted which were not attempted in the old days. When Whitworth appeared on the scene, he

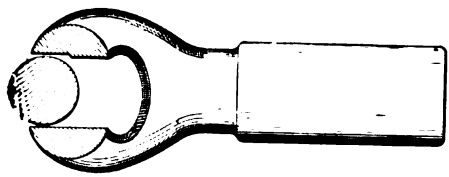


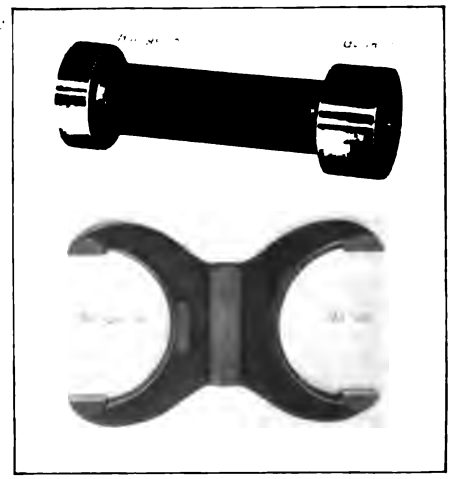
FIG 2

found the foregoing state of affairs in full swing, and set himself to cheapen construction and repairs by standardisation and improved gauge methods. Hence arose the Whitworth screw thread system which displaced a myriad of screw sizes. Whitworth gave particular attention to standard gauges, and introduced his ring and plug gauges, accurate to a minute fraction of an inch, and he perfected measuring machines which made fine measurement and the manufacture of fine gauges possible.

Standard gauges, however, are not suitable instruments for shop work. To make a running fit by aid of a standard plug and ring gauge,—remembering that a plug of a certain size will not enter a hole of the same size,—the hole must be bored so that the plug gauge will enter it and the shaft must be turned so that the ring will slide upon it. Then it is certain that the shaft will enter the hole.

But this does not make good work. A shaft may freely enter a gauge with a difference of 0.0002 inch, and a plug gauge may enter a bored hole with the same difference. Hence the turned and bored pieces may differ by only 0.0004 inch. But this is too little play for lubrication. Standard-gauge working, therefore, resolves itself into making each running piece slack in its respective gauge, and this slackness at once brings in the individual opinion and judgment of each workman concerned. Obviously, to work to a standard gauge is in no way better than the old system of rod gauges. Indeed, unless actual pieces are brought together, there is no certainty in absolute gauge working except that pieces will go together that have been made to a pair of gauges, but how slackly cannot be known.

It has long been recognised that no two pieces can be made alike, and that the nearer they are made alike, the more costly it will be to do the work. This expense was a feature of the old style of working, because, having a single fixed gauge to copy, the workman did not know where to stop in securing the proper degree of accuracy. Experience teaches that so-called interchangeable work may really be so in all respects as to proper fit, sufficient allowance for lubrication, and so on, and yet, if the whole of the pieces were carefully meas-



FIGS. 3 AND 4

ured, they would all be found different. There would be fits wherein the largest shaft of a lot was found with the smallest bored wheel, and the smallest shaft became mated with the largest bored wheel. Yet all are properly classed and act as good work.

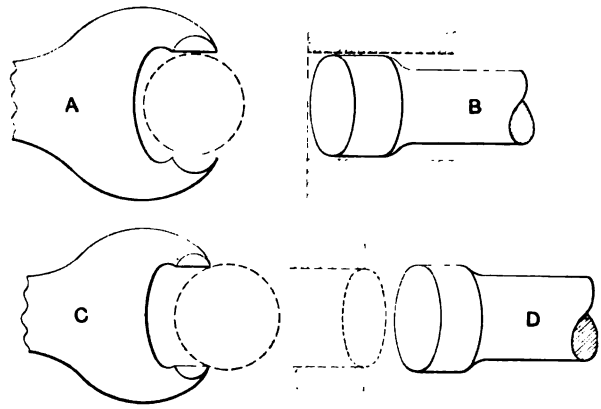
If, then, we measure the extreme pieces and find that the extreme diameters of holes differ by 0.002 inch and the extreme shafts differ by 0.0006 inch, we may conclude that, with this particular class of work and the allowance for lubrication, the above range of total departure from nominal size may be allowed without detracting from good work.

FIG. 5

If we procure a snap gauge, one end of which is 0.0006 inch larger than the other end, and employ this gauge to measure a shaft so that the large end of the gauge slips easily upon the shaft while the other end will not go on the shaft, then we have certain evidence that no two shafts thus made can possibly differ by so much as 0.0006 inch. As soon as the shaft has been reduced below the size of the larger end of the gauge, the workman ceases further effort, for he has performed his share of the contract and turned shafts within the given limits of size.

Obviously, the rapidity of the work is increased. There can be no need to exercise opinions. If a gauge drops on the piece, there can be no two opinions as to the matter, for no forcing of a gauge is allowed. It must slip on without resistance preferably,—without more than its own weight at the very tightest. The " not-go-on " end must not go on, though it may be allowed just to begin to go on. Similarly, with the internal gauges for boring, one must drop easily into the bored wheels; the other must, at most, just begin to enter. Work thus done with properly designed gauges is then both good and cheap, and it is interchangeable.

Limit gauges have, like other tools, passed through periods of change and evolution. Fig. 1 shows one idea for a limit caliper gauge. It has a sloping jaw, and is marked across with two lines, some distance apart. Midway between the lines the jaw measures the normal size arrived at. By suitable choice of the angle of the jaw, shown much exaggerated, the span at *a b* shows the largest permissible diameter, while *c d* shows the minimum size. So long as a turned piece enters the jaws to any point between the two cross lines, it will be within limits. This gauge is theoretically perfect. In practice, however, the angle between the jaws is so very acute that the gauge is apt to become strained and to wear rapidly. This form of gauge can be better arranged as a wire gauge when its angle may be considerable. A form that may sometimes be used with advantage is that of Fig. 2. In this the limits are measured at two sizes. The step between represents the range or tolerance. The objection to this gauge is that it is difficult to accurately finish a stepped surface like that on one jaw so as to secure parallelism of each step with the opposite face and at



FIGS. 6 AND 7

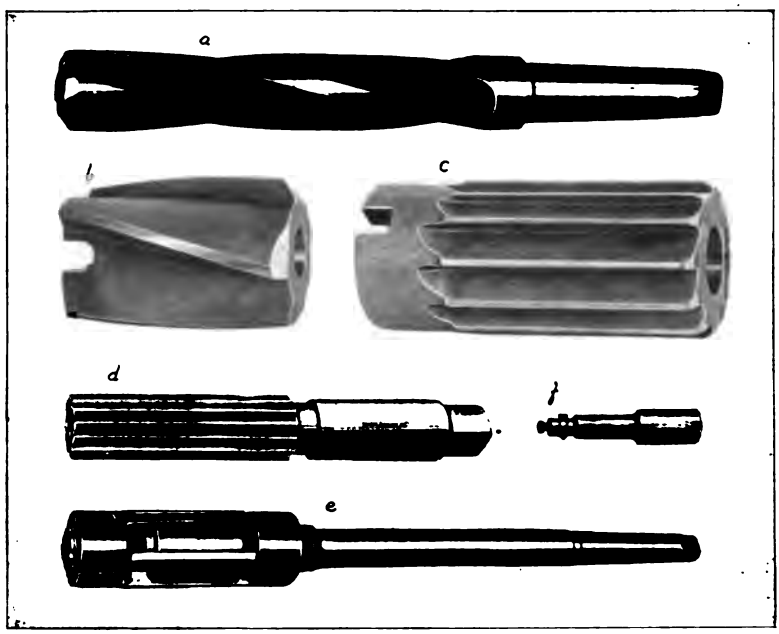


FIG. 8

the same time keep to correct limits. The common and best kind of gauge is that of Fig. 4, which represents a form of gauge for shop work. The accuracy of a gauge like this is 0.0001, which is amply sufficient for the best class of work. The companion gauge for internal work is shown in Fig. 3. For sizes above 4 inches, owing to the weight of plug gauges, the spherical-ended rods shown in Fig. 5 are best used in pairs, with handles of black and of red ebonite to distinguish the two limits.

It is a marked advantage of the limit gauge system that, having fixed upon the widest limits that can be allowed in the gauges, so that a piece made to either extreme of the internal gauge will produce good work if mated with a piece made to either extreme or the other gauge, the results in practice will be that the pieces made are better fits than the gauges imply. Thus, the worst possible cases will be when a shaft of maximum diameter is mated with a minimum hole, or when a minimum shaft is mated with a maximum hole. In Fig. 6 the full lines are meant to represent the gauges of the first case which have gauged the shaft and hole. They are shown, for clearness of argument, nearly of the same size. Both these gauges being properly used will produce pieces respectively smaller than the gauge *A* and larger than the gauge *B*, as shown dotted, and thus two gauges, tight to each other, produce a running fit in the gauged pieces.

Similarly, when a minimum shaft gauge is set against a maximum hole gauge, as shown in Fig. 7 in full lines, these being the "not-go-on" and "not-go-in" ends of the gauges, the shaft must be bigger than the gauge *C*, and the hole must be smaller than the plug gauge *D*. Here, again, where the plug gauge might give too large a hole and the shaft gauge too small a shaft, the pieces actually produced are more moderate than the gauges. The mean of the two ends of the gauges is approximated in practice by the pieces made.

With a limit gauge system correctly thought out and designed, the results

attained by it will be correct. The attempt to do absolutely accurate work would result, as already stated, in certain departures from absolute accuracy to the extent of human fallibility. If, then, work is always inaccurate and yet is good, it is obvious that no attempt need be made to secure perfect accuracy.

But a line must be drawn somewhere or the work would become hopelessly bad. The limit gauge draws the limits within which human fallibility, temperature differences, and machine inaccuracies may fight out results. All work that comes inside the chosen limits is good; all pieces that transgress beyond the limits are rejected as bad and must be remachined, if this can be done, or scrapped before further labour is wasted on them.

One advantage of the system is that there can be no dispute between the workman and the inspector. If a piece does not pass the limit gauge, it is wrong, and there can be no personal opinion such as may exist as regards the fit of a standard gauge; for a fit is, after all, a matter of opinion and judgment. But the limit gauge does not destroy skill. The most skilled man is he who, with least trial and error, machines a piece to drop easily into one end of the gauge and stick at the other end. Limit gauge working represents the outcome of the desire to do honest work well and cheaply, and within the limits of skill or the range of human fallibility.

To carry the system out in a thorough manner there must be a properly organised system. It is best to commence from the bored hole. All machinery contains wheels, shafts, and bearings. The holes are first made, and the department for making true cylindrical holes is the one of first importance in a factory. To make true holes cheaply demands good machine tools and a suitable line of tools to use in them, as shown in Fig. 8.

In the case of a solid boss a common twist drill may first be put through. If the hole is cored, a single-point boring tool, *f*, clears it out best. In either case these tools will then be followed by a pointless three or four-lipped drill, *a*, or by a four-lipped boring tool, *b*. Both these tools measure from 0.01 inch to 0.02 inch less than the finished hole. These tools are followed by a reamer, like *c* or *d*, according to circumstances, and by an adjustable reamer, *e*, which serves to fit the hole to the limit gauge when the first reamer, *c*, has worn below size.

In American practice the first reamer, *c*, will often get through a large number of holes before it becomes too small, but in British practice, with harder materials, the adjustable reamer is imperative from the first. A vertical turret machine with a five-hole turret is one of the best machines for the foregoing work, as it is so easy to chuck the work on the horizontal face-plate of such a machine, and the work is well in hand. Such a tool will do twice the work of a lathe on half the ground space. Horizontal chucking machines are also used for suitable pieces of work.

There is usually allowed a greater range of limit on an internal gauge than upon an external gauge. It is essential, for commercial reasons, to do so, partly because of the expense of the boring tools. For pieces turned on the lathe, as shafts and spindles, the tool is often but a cheap and simple bit of steel; and, moreover, many pieces must be ground to a finish, and it is so easy to grind closely to size that smaller tolerances may be allowed than are advisable for boring operations.

Modern shop practice points to the elimination of the lathe for much fine work. It appears probable that for much of this kind of work the lathe will be used simply as a roughing-out machine, taking heavy cuts and leaving a rough surface, and that the finishing operation will be performed by a powerful grinder with a wheel of 20 or 24 inches diameter and a face of 2 inches. So far, the grinding frame has been looked upon rather as a machine for the fine finish of the hardened steel spindle of a lathe, or drill, or the arm of a milling machine, or as a means of grinding a fine gauge to size and accuracy; but the present tendency is to extend

the system to axles and engine shafts. For roughing-out purposes the same system of limit gauges may still be employed, with the difference that the tolerances will be wider and the gauges can be used longer and adjusted, when worn, in a rougher manner than is possible with a finishing gauge. It will always pay, even on the roughing-out lathe, to do work to a limit gauge that will send forward pieces with reasonably equal amounts to be removed in the grinding frame.

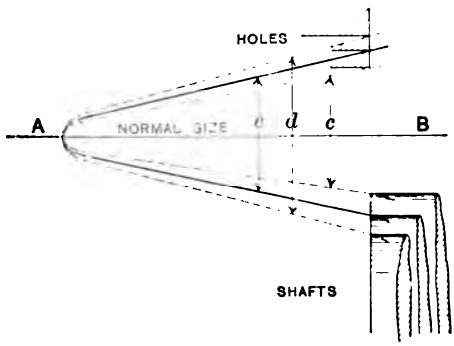


FIG 9

In Fig. 9 are shown, enormously magnified, the differences between a series of shafts and holes considered proper for lubrication. The horizontal line represents nominal sizes. On each side of the nominal size are three sloping lines, the two centre lines showing by their distance apart *c*, the allowance considered best for lubrication, while the two outer lines in each case show the departure on each side of this line o the two ends of the limit gauges. Thus, the extreme outer lines, *d*, represent the case of a minimum shaft coming together with a maximum hole; and the two inner lines, *c*, show the case of a maximum shaft and a minimum hole.

If these extreme cases both run well, it must be clear that any intermediate sizes and fits will also be good. It is also extremely improbable in practice that absolute extremes will meet, and when they do happen to meet, though still good work, it is yet open to the erector to use his judgment, and, if he think a fit too easy or a wee bit tight in any pair of pieces, he can simply change one of them. The probabilities are all in favour of the system producing good work with a minimum of cost and an almost total abolition of shop disagreements over inspection.

Experience in limit-gauge working has all been in the direction of proving that really good work is done with far greater allowances from absolute accuracy than has been thought to be the case. The gauges have been closer than they need have been. This points to the work being better than the gauges, and tells us that when workmen become better acquainted with the system they secure better results.

It would take too long to discuss the whole question of limit-gauge working as applied to different classes of work. Textile machinery, for example, admits of an easy fit of parts and wider limits than would be sound for machine tool work. Engine work falls between the two. Heavy machinery for dusty localities demands freedom and room. But no matter what the class of work, it can all be suited with its proper gauge allowances, and its production is then cheapened. Indeed, in some respects it may very well be claimed that a limit gauge system is of greater value to heavy, rough work than it is to very fine work that may sometimes be made to standard gauges. Coarse, heavy work with large lubrication allowances cannot be made to standard gauges, because the oil space leaves too much room for the range of human judgment and individual

FIG. 10

opinion. A standard gauge fixes only one limit, beyond which work must not go. It puts no limit on the opposite extreme. It is, therefore, not a general manufacturing tool in the sense that the limit gauge is, and there can be little doubt that the attempt to employ standard gauges as general shop tools has told heavily against the system of gauge working generally, having frightened people who had expected good results by the failure to produce good results.

Standard gauges have their own peculiar field; but it is chiefly in the tool room department and in the hands of specially skilled men of the toolmaker class who are able to form better opinions than can be expected from the cheaper class of labour. Such men are called on to do really close work, and standards are proper tools to employ. But machines and engines are made in quantity to sell. If too dear, they will not sell. They must be manufactured to-day and not built. But in manufacturing on modern methods it is not necessary to use a minimum of material such as some ill-informed critics of British methods would have done. The limited material idea was a mere passing craze that inflicted itself most seriously on a certain section of American manufacturers. The better American engineers have rejected the fallacy, and make machinery fully up to British standards of weight, and some of them have also departed from the bad practice of using unduly soft materials.

While British practice has appropriated the good points of American practice, the Americans have not been idle in adopting British characteristics and aiming at greater durability. It is probably the case that the gauge system of working, which was of British origin, has been far more widely adopted in America than in Great Britain, but the limit-gauge system has in no country received the wide and general recognition of which it is deserving. Indeed, no one could seriously think out the system of manufacturing to gauge without being compelled to acknowledge the limit system as the only possible solution of cheaply producing good and interchangeable work.

Gauges are expensive, but soon pay for themselves. Their tendency is to standardise sizes. Many works using dimensions in sixteenths of an inch could easily abolish any gradation closer

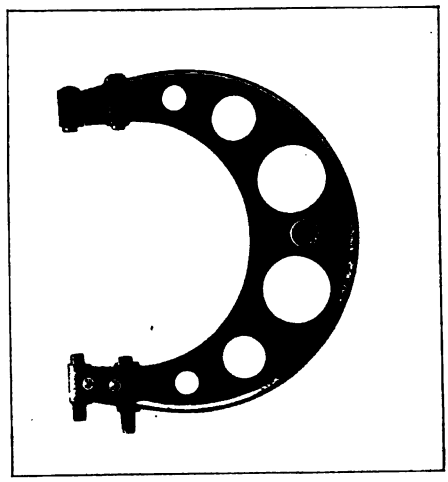


FIG. 11.

than ⅛ inch, or even ¼ inch, as a rule. It can rarely happen that a stud of 1 11-16 inch cannot be made either 1⅝ inch or 1¾ inch. It is an advantage to reduce the number of sizes, and can always be arranged by the draughtsman. Dimensions so fine as 1-16 or 1-32 inch, as a rule, are wholly unnecessary in practical work.

Though so old a system, working to limit gauges has until recently not had a wide application. Prominent engineers doing good work will still adhere to the use of standard gauges, eked out by thin paper for fit differences. Probably this is due to want of elasticity of the system of rigid gauges which, once chosen, cannot be altered in limit, except at an expenditure forming a very large proportion of the cost of a new gauge. To meet this want, the Newall Engineering Company, of London, have introduced their adjustable gauges, which are made in the form of a crescent, as shown in Fig. 11. There are two anvil pieces fixed in one horn of the crescent, and two screws in the other end

which are drilled for and tapped in a special machine to ensure the axis of the screws being perpendicular to the plane of the flattened points. The screws are a firm fit in the threaded holes, and are further clamped fast by binding screws.

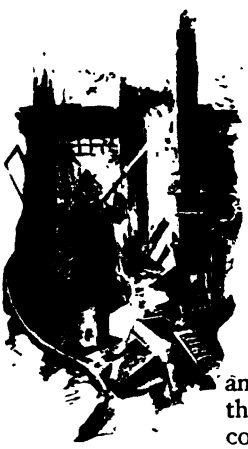
This one pair of screws and anvil forms the "go on" gauge and the other pair forms the "not go on" end. Such gauges are first set to a standard setting bar, and then, by means of a pair of discs, one of them divided into even degrees on the circumference, the desired limit can be added or subtracted from the standard setting. The manner of doing so is as follows:—The discs have small central stems on one side which fit into central holes in the screws to be adjusted, and the edges of the discs overlap slightly. The zero of the divided disc is set to the mark on the other disc, and then by a screw-driver the screw is turned, carrying the disc with it through the desired number of degrees to give the difference of size. The adjustment of the gauges is, of course, a tool room job, and when any workman takes out the tools for any special piece of work, he takes with him a newly adjusted gauge.

Six different sorts of fits are suggested, viz., force or shrink; driving; push; and running fits, the last class having three divisions of fine, medium and coarse, to suit different classes of work. Obviously whatever kind of work is in hand can be arranged by suitable adjustment of the gauge. The writer has suggested that each of the six fits should be distinguished by a colour or number so that when a gauge was set to any limit a coloured or numbered label should be attached to it in order to safeguard its use on other fits. A numbered label would enable the draughtsman to place fit numbers on the parts in a drawing. In order that the limit gauge system should make headway, it seems necessary to cheapen its application, for at present many engineers who believe in the system are restrained from adopting it by the first cost.

The adjustable gauge diminishes first cost to a trifle and practically enables a shop to get along on no bigger first cost for gauges than when standard gauges and paper are employed, and the upkeep and after cost are less. The writer has often urged that the limit gauge system is the only one that enables work to be done at once good, accurate, interchangeable, and cheap, and if the first cost can be cheapened the system will undoubtedly extend. It is a sign of the intended interest taken in the system that an English manufacturing firm should have undertaken the manufacture of limit gauges as above noted.

FIRE PREVENTION FOR MACHINE SHOPS

By Albert Blauvelt



SOME men are under the delusion that where a fire hazard is not visible, none exists, and, therefore, there is no need for fire prevention. The most noteworthy examples of this conceit are furnished by those who have passed many years without having had a fire in any property with which they may have been connected. But a little reflection should make it clear that the experience of one lifetime in the care of one property is no criterion as to what to fear, or not to fear, from fire.

Many machine shops insure at about 1 per cent. per annum, and as no insurance company can pay out its entire revenue in losses, to the exclusion of taxes, expenses, and compensation on the capital invested, it follows that a property insured at 1 per cent. is admitted to have a probable life of, say, one hundred and fifty years. Hence, the property must be preserved through not only one man's working days, but also those of several successors, if it is to justify the estimate put on its fire life. Under these circumstances it must be clear that no one would deliberately accept a risk at such long odds, admitting the odds to be fair and usual, except in the absence of any visible, immediate hazard. But visible and immediate hazards, which can be clearly understood, are on this very account largely weeded out by propertyowners, and thus become comparatively infrequent, leaving destruction by fire to arise usually from some obscure, unsuspected, and unfortunately often unknown, cause. If a man knew where the points of jeopardy to his property lay, he would remove them and dispense with insurance; the fact that he does not do so proves that he is not a sure judge of hazard and cannot hope to be.

Fire prevention, therefore, is an art which is indefinite as to results, is based merely on general principles, and, in that it strives to eliminate hazards not visible nor readily provable, seems visionary, far-fetched, trivial in detail, and tedious in application. How far to pay attention to a subject so seemingly vague, so seemingly needing no immediate attention, or which may have had careful attention, is a question always unsettled and never capable of an exact decision. Fire *prevention* may be regarded as the art of not having fires, in distinction to fire *protection* or the art of confining and extinguishing fires.

While fire protection is more successful, when fully carried out, than any system of fire prevention, however faithfully practiced, or while, in other words, it is possible in manufacturing establishments to be more successful in saving loss by fire, by reason of successfully and cheaply extinguishing fires than by any means or system of preventing fires, yet, in machine shops, the commercial conditions usually warrant special attention to fire prevention rather than to fire protection, this, because of the fact that while machine shops are known in insurance phrase as "special hazards," they are not classed as extra hazardous, and ordinarily command a rate of insurance sufficiently low not to warrant so heavy an expenditure for fire protection as is requisite to secure a specially low insurance rate by reason of a refined system of protection. Fire

prevention, on the other hand, is cheap and always of value toward securing a favourable insurance rate, as well as a preservative of the uninsurable interests of the machine shop, such as loss of trade, scattering of men, loss of special uninsurable drawings, jigs, dies, patterns, etc., all of which matters assert their value as never before, directly an establishment has burned.

Ordinary machine shops, and foundries in connection with them, suffer from a fairly large number of fires from sparks. Such sparks come sometimes from the top of the cupola and sometimes from back draught down the cupola after the bottom has been dropped and before the lining has cooled. Other sparks come from the boiler stack when starting fires with wood kindlings, if not during regular running. Sparks issue also from the brass furnace flue under the same conditions noted as to boiler stack, and the same may be said of any furnace or forge using a closed draught.

These sparks cannot be prevented, but care can be taken to prevent their igniting the roof by seeing that all roofs are well metaled, or graveled, doing away with wooden gutters, wood slatted ventilators, or wooden frame skylights. Slate roofs have a fatality for attracting sparks whenever a slate is broken, and should have close attention to repairs, especially where pattern storage is under them.

Any flue from a brass furnace or other closed draught passage carrying hot gases should be examined by feeling with the hand where the flue passes through the roof. It is a peculiarity of some such flues that although the hand may be placed on them without inconvenience at points relatively near the source of original heat, they may be much hotter, dangerously hot, in fact, near the free air outlet of the flue. Whether this is due to a recombustion of gases as the stream of heated gases reaches the fresh oxygen of the outer air, is left to the conjecture of those who care to meditate thereon, but it is a fact that a flue may be cool near the furnace and very hot near the roof. Such flues can be cured by lengthening them so that the hot portion or part near the outlet is carried up or away clear of all woodwork or buildings.

Any flue, stack, forge setting, steam pipe or similar device when too hot to be touched by the hand is too hot to remain in contact with wood or similar material. Fires from steam pipes laid in sawdust, incandescent lamps having paper shades, dry, punklike wood igniting in dry-rooms or kilns or near boiler stacks, constantly show the truth of the above statement.

The writer can confidently assert, from a fairly extended observation, that there is no safe way of passing a metal boiler stack through a wooden roof Large thimbles, asbestos backing, good ventilation, etc., are usually deemed sufficient, usually approved by insurance men, and are sometimes, but by no means always, permanently successful. The tricky nature of baked wood exposed to intermittent radiant heat is such that no man can tell whether it will ignite at all, or ignite in six months, or in ten years. The only sure method of fire prevention where a metal boiler stack passes through a roof is to make the roof all metal, or tile, or equivalent for a large section, say, about 8 feet square, with the stack passing through the centre of the special section of roof.

The hazard of spontaneous combustion from shop sweepings and oily waste is probably universally understood. The use of oily waste cans and trash cans of all kinds is open to some question. Oily waste and trash cans are innocent enough if some regular system of discipline exists whereby they are regularly emptied at night. While oily waste cans are built on legs and with spring top covers for the purpose of confining any fire which may arise from spontaneous combustion of the material within the cans, few shopowners would deliberately care to trust one of these cans to confine such a fire as is invited every time a can full of waste or trash is left over night in the shop. Certain shops decline to use any waste or trash cans and throw all waste out to the middle of the floor, at the same time making

provision for regular cleaning, particularly before nightfall. In this way all objectionable matter is wholly removed promptly. Oily waste cans are insisted on by insurance interests in some localities, and, again, are preferred by some shop managers; but caution is always needful to have the cans emptied regularly at night, and the same rule should be applied to trash boxes, bins, or carts, all of which should be of metal rather than of wood.

Spontaneous combustion fires can occur in machine shops where sal ammoniac is used, in making rust joints, for example. Sal ammoniac mixed with shop sweepings and iron borings is subject to heating if wetted. Linseed oil and shop sweepings also form a quick-heating compound. Ashes in wooden boxes and oily chips in wooden boxes or against frame buildings have been known to cause fires.

Fires about the boiler room, in addition to the liability already touched on as to hazard at the boiler stack, are partly to be guarded against by instructing the fireman on no account to allow the shop carpenter or the pattern maker to use the top of the boiler setting for drying lumber, also to keep no unnecessary planks nor other combustible on the boiler setting. Boiler settings are subject to sudden cracks in the masonry, which let out flame or gas and ignite combustible material within reach. Wooden roofs over boilers occasionally catch fire simply from the treacherous nature of baked wood exposed to radiant, and particularly intermittent radiant, heat, as already noted in connection with boiler stacks.

Boiler room fires also occur from fire or sparks creeping or drifting from the ashpit at night and reaching kindlings which the fireman has carefully piled in front of the boiler on the fireroom floor. There appears to be no way of wholly preventing fires from this cause. The fireman will have kindlings or trash for burning, and usually has no place for such overnight except on the fireroom floor; but care can be taken to wet down carefully and to sweep a clean space between the kindlings and the boiler front, and also to close the shavings or fuel vault door tightly if the shop uses any wood as fuel.

Foundry fires can be prevented to a great extent by guarding against the ignition of the structure proper from various ineradicable causes of fire. Sparks issuing from the charging mouth of the cupola can be made harmless by fully overlaying the charging floor with iron, or, better still, by building this floor wholly of iron and putting an all-iron section of roof around the cupola at the roof. Every cupola should have two sections or stands of hose available for wetting down when the bottom is dropped, this to guard against depending wholly on one line of hose for this service. Foundry fires from hot castings or smouldering flasks can be prevented from reaching the main roof via wood posts or partitions by covering such posts or partitions for a few feet from the floor with wire netting filled with neat Portland cement.

Never use sheet metal as a heat shield over wood. It is true that tin is used to cover fire-doors and shutters, but in that case the tin forms a complete envelope over the door or shutter, and it is the complete envelope which constitutes the protection. Partitions, roofs, sides of buildings, etc., exposed to heat can be cured only by removal of the wood or the heat, or by a non-conductor covering and not by sheet metal. A very valuable and very little appreciated covering for wooden surfaces is plain wire netting. A wooden surface closely covered with screen-door netting or any metal net, preferably galvanised for durability, up to ¼-inch mesh, is incapable of supporting a flame. The net does not dry-rot the wood, as does a sheet metal coating; the net and the wood can be kept painted if desired, but must not be whitewashed nor painted with any of the "fireproof" paints which rust out the wire. Roofs having plain surfaces and no bulk of combustible materials beneath, can be covered underneath with wire net to great advantage. Exterior exposure fire can also be prevented in connection with foundries by

piling the iron flasks nearest the buildings and wooden flasks further away, rather than to stack wooden flasks under the eaves of the building, subject to every chance spark in the air.

In the pattern makers' department the glue heater should be steam heated, or, if gas heat is used, it should be all enclosed by a deep cast-iron pan on raised feet or legs. Pattern makers' lampblack should be kept in a securely dry place, cold wax should be used at benches, and no wax tool heating lamp should be allowed. Pattern makers should not be allowed to use any type of lamp or lantern having the burner so arranged that it can be taken out and used as a naked torch. If the pattern maker is not provided with a small, handy light similar to a closed bull's-eye lantern he will be sure to use a candle, or remove the burner from an ordinary lantern, or resort to striking matches in looking over racks of patterns for the marks or numbers used to identify the patterns. The carrying out of fire prevention in pattern lofts is dependent more on the shop management in providing the pattern maker with a safe light, small enough to use between and beneath patterns, than on any orders or rules, which are sure to be disobeyed if inconvenient means of lighting are retained.

Where electric light is available for pattern lofts, the less wiring and fewer switches in the loft the better, and the possibility of fire can be decreased by using "marine portable" or "navy portable" instead of common flexible cord as a connection from the main wiring to the incandescent lamp used as a hand lamp about the pattern racks. "Marine portable" or "navy portable" is a very strong and well-wrapped flexible cord, about half an inch in diameter, far more durable and safe than common electric cord, and takes its name from the fact that it was specially designed for use about the decks of vessels. Pattern lofts, where not often used, are sometimes resorted to by employees who seek a secluded place for a quiet smoke. The chance of such a hazard existing naturally depends on the particular loft and shop, and whether care is taken to keep the pattern storage spaces closed to the common run of the employees.

Fire prevention related to causes in connection with the general heating arrangements of a machine shop, is best carried out where some one good general heating system is used, as by exhaust steam pipes located overhead in rooms, or by fan-driven hot air duct systems. Where hot air circulation is used, special caution is desirable to remove all combustible material or possibility of fire near to the inlet to the heater coils at the fan. A small fire, once drawn into the fan blast, is immediately driven to all parts of the premises through the ducts. Shop stoves usually connect with brick wall flues, and as the shop men never hesitate to fire a shop stove until it is nearly ready to melt, it is a good caution to have the flues pointed up by a mason in the fall of the year, particularly if a flue passes through an attic. The same idea applies to brass furnace or similar flues.

Properly installed electric lighting is safe. The lack of fire prevention pertaining to lighting in most machine shops is either because of using petticoat lamps, swinging gas jets, railroad torches, gasoline torches in foundries, etc., none of which can be made safe, or by retaining obsolete electric equipment. The worst features of old electric equipment are the retention of old-style, open arc lights, particularly in woodwork departments, in place of modern "bottle arc" lights, which are safer and more suitable for general use, the retention of overloaded wiring, and frail, flexible cord in storage or pattern departments.

One curious cause of fire in machine shops doing much emery-wheel dry grinding is the finely-divided metallic dust which settles on the overhead timbers of the grinding room. This dust, if wetted from a leaky roof, or by water spilled and leaking from a floor above, will heat and ignite the woodwork. The writer has seen a cavity burned deep into the upper face of a timber from this cause, and other instances are

on record. Some experienced grinding room foremen use care to clear the deep dust from all overhead timbers quite as much as to keep other parts of the department clean.

Machine shops with buffing or polishing departments using rag wheels are subject to fire either from spontaneous combustion, or sparks in the refuse or fluff from the rag wheels. Apparently the only preventive of fire from such a cause is to use a collector system and have the discharge outlet or dust collector placed outside the building.

Machine shops also can profitably have attention given to prevention of fire from miscellaneous causes, such as rubbish, or flasks, piled on core ovens, benzine cans or paint stock kept in main buildings, oil handing in the presence of naked lights, carelessness in running shafting in all departments merely because one department happens to be running overtime, draughtsmen throwing cigar stubs in wastepaper baskets, foreign workmen with plumbers' fire pots, or paint rags, etc., all of which can be prevented from doing harm only by a good system of general care and cleanliness.

No system of care or cleanliness can succeed where the main buildings are used to store junk. A prerequisite to a clean shop is to move all needless trash out into yard sheds or elsewhere, so as not to obstruct the sweeping of the main shops. In the foundry, boiler shop, or smithy there is the same need for a clean floor, unobstructed save by legitimate work and machines.

The more storage is provided for in he way of racks and shelving, rather than under benches, the less opportunity there will be for floor dirt to collect in places hard to keep clean. Having provided for as much clear space as the working conditions offer, the next step toward cleanliness is to not take the sweeper away from his work, and not be too good-natured in letting the sweeper follow his own inclination. A shop sweeper is often of material which has failed to become a mechanic, and will usually sweep the centre of the floor and do nothing for the out-of-the-way places. In bossing sweepers, always order them to clean the cellar, attic, the spaces under benches, closets under stairs, and similar places before giving any attention to the clear floor space. It will then be found that the clear floor space will almost take care of itself, and the establishment will be in a condition to pass inspection throughout.

In the inspection which necessarily attends the keeping of a clean shop lies a large part of the fire-preventing value of the cleanliness. An establishment, by reason of being kept clean, secures a double inspection automatically, first by the sweeper or cleaner, and second by the boss who inspects to see that the sweeper does good work.

The practical application of methodical fire prevention is apt at times to be a hardship to machine shop men who have a thousand other matters calling for their best strength and attention; yet there is no choice save to attend to the fire prevention or deliberately ignore it. It is certainly true that human nature cannot be constantly on the alert on any topic, much less on matters so indefinite as fire hazards which seem inactive. The most satisfactory and effective method of preventing fires is to make the caution and general preventive measures as much as possible part of the habitual routine of the plant. One measure to this end is to use fairly severe discipline among the employees for all cases of disobedience or carelessness respecting fire. One man discharged for using a torch to look for patterns, or for leaving the fireroom floor in bad condition, or for putting rubbish on top of a furnace-setting will do more to keep a shop full of men from similar lapses than all the signs and orders imaginable if unenforced.

Another excellent measure is to use the night watchman as a reporter, furnishing the man with a pad of printed blank reports, with space for notes. In this way the shop management can secure, without extra cost, a nightly report not only as to care of hazards, but also as to misplaced stock, or tools, or other shop disorders of immediate interest. The value of cleanliness, and

the double inspection noted as caused by it, are always reckoned as of prime importance, and are habits quite as easy to acquire as that of permitting a shop to become cluttered with assorted junk. Jobbing shops are particular sinners in this last respect.

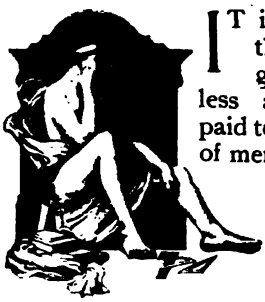
Good fire prevention also demands a regular, occasional, or at least annual, full and complete inspection by the management, with a view to weeding out all the hazards that can possibly be weeded out, however remote. It is nonsense to suppose that this is attended to by the insurance companies. Some districts have no competent inspection; some insurance interests do not believe in talking to the propertyowner, but wish information through inspection solely for their own guidance; and in some cases absence of complaints from insurance quarters may indicate merely that the shop is looked upon as paying a high enough rate for its faults. Like many another matter, the weary machine shop man must make his own inspection to make sure of its being done.

A last, but not least, essential toward fire prevention is the cultivation of a suitable temper, embodying a willingness to take pains to avoid what, individually, are highly improbable dangers, yet which, collectively, constitute a recognised risk, a habit of general attention to the subject, and a well-directed discipline against all employees who show a lax or contrary bent.

THE QUESTION OF APPRENTICES

HOW IT IS SOLVED IN THE UNITED STATES

By E. H. Parks, M. E., of the Brown & Sharpe Manufacturing Company



IT is undoubtedly a fact that during the last generation much less attention has been paid to the proper education of men to fill places in the rapidly increasing number and enlargement of factories engaged in the manufacture of machine tools, steam engines, electrical machinery, and work of a similar character than was the custom earlier. Before that time the demands for skilled workmen were met by training boys under the immediate supervision of the master himself, and boys bound out for a long period were taught the details and intricacies of the business, as it then existed, in a most thorough manner. One of the greatest advantages of this system, when the master was a man of skill and of character, was that the boy was brought under the personal influence of such a man, and was helped in a way that is not possible under present conditions.

With the great aggregation of capital and the large concerns of the present day it is a question whether those interested in them lay stress enough upon the matter and take proper steps towards securing the help in the factory that may be requisite for carrying on the business. Capital can be raised to equip the shops, in many cases the right kind of officers can be hired, and there are many men who can be obtained to do the common work of the shop; but the skilled workmen, loyal to their employers, working for their interests in all ways, cannot be picked out from the crowds clamoring for employment. They can be secured only by training, starting from their earliest employment in the shops.

The technical schools have, in a measure, attempted to supply this lack of skilled workmen; but the results, while excellent in many ways, do not bring out a class of men with the training and experience needed, so that at the present time it seems as though there were but one way to fill this want, and that is by returning to the old apprenticeship system as nearly as it can be done in a large factory. As in a large institution of learning, it is not possible for the student to be brought into close contact with the head of the establishment; but this want can be supplied, in part at least, by having all who have to do with the apprentices thoroughly imbued with the idea that these young men are not only to be taught the details of the trade to which they have apprenticed themselves, but are to be taken care of and supervised in all their relations, both inside and outside of the works, during the time of this apprenticeship.

In addition to this, when a factory is large enough to warrant it, a competent instructor can profitably be employed to attend to all the matters relating to the apprentices. This instructor can see to it that proper selections are made from the applicants; that they are given correct instruction in the shop; that they are changed about from department to department as time progresses; and he should be a man of character, to whom the boys can go for advice and counsel, and who can look out for them in the many ways that will occur to anyone who is truly qualified to take charge of apprentices. A man qualified to fill such a position should be a man of ex-

ecutive ability; should have a good knowledge of human nature; understand the mechanical work that is being undertaken by the boys, and have a patient spirit and gentlemanly bearing. And, above all, he should be thoroughly sincere; otherwise he cannot command due respect from the boys whom he is to guide. With the supervision of such a man it is possible to bring up young men who will be properly educated in the business, and not only fitted to do the ordinary work of the shop; it will furnish foremen and those who may eventually become managers.

I have written to many concerns engaged in the different branches of the machinery business, asking them regarding their system of handling apprentices, and find that there is an entire lack of uniformity in the United States among the different manufacturers at the present time. In some of the shops apprentices are hired as any ordinary workman. They are apprentices only in name. There are no agreements on either side, and it is really difficult to determine the difference between such so-called apprentices and the workmen who come to do whatever they may be called upon to do. On the other hand, I find some concerns employing men who look out for the interests of these young men, giving them a most thorough education in the details of the work.

While it is not possible to obtain as apprentices young men who have had the advantages of higher education, it is possible and necessary, provided we are to train men that are to fill more than the merely common workman's position, that the young men should have at least had a common school training, which gives a knowledge of the rudiments of arithmetic, and enough training to enable them to understand what it means to be taught and to receive instruction.

While it is not, perhaps, possible to adopt a uniform system of apprenticeship,—one that will apply to all places and all classes of work,—I believe that it is possible to provide a system that, in the main, will meet the requirements of all establishments interested in such a plan. First of all, as just mentioned, the young man should have had a preliminary training, which should be helped out by additional work while under instruction in the way of a better knowledge of mathematics and ideas as to drawing; and then it would be possible to plan, in a general way, the time that should be spent in various classes of work, many of which are common to all lines of business. An apprentice in an establishment devoted to the building of locomotives, steam and gas engines, and electrical apparatus of the larger variety would need treatment entirely different from one engaged in a shop manufacturing, say, lathes, drill presses, and screw machines. As in any kind of instruction, however, the method and thoroughness of the instruction would amount to far more than the mere detail of it.

Of the 112 establishments from whom answers were received by the writer as to their treatment of apprentices, 56 take their apprentices for a four-year term; 17 have a three-year term; 17 have no system of apprenticeship; 6 have tried a system and abandoned it for various reasons; 12 hire boys, paying them according to ability; and from 4 the information received was not sufficient to classify them. Of the 56 that take apprentices, 49 use some form of indenture or agreement; 7 require a deposit before entering into an agreement, which deposit is returned upon the faithful completion of the term, with a further sum added as a bonus; 40 of these 49 pay a bonus; 4 hold back part of the wages due, to be paid at the end of the term if faithfully completed; and one of the establishments pays extra for full time made,—that is, calling fifty-eight hours a week. If this is made, the apprentice is paid for sixty hours at a varying rate of wages for each year, which makes it possible to have as a bonus $175, or more, at the end of the term.

The table at the top of the next page shows, in detail, the different facts regarding these shops, and it is of interest to note the differences existing among them.

APPRENTICESHIP DATA FROM 112 SHOPS.

Character of Articles Manufactured	Number of Factories	Apprentices 4 Years	Apprentices 3 Years	Apprentices no System	Apprenticeship System Abandoned	Hire Boys but no Agreement	Information Complete	Indenture or Written Agreement	Pay Bonus	Require Deposit
Machine Tools	41	25	8	4	2	2	0	21	18	5
Engines (all kinds) pumps, etc.	37	21	4	6	1	3	2	17	13	1
Electrical machinery and miscellaneous	34	10	5	7	3	7	2	11	9	1
Total	112	56	17	17	6	12	4	49	40	7

Among these concerns the writer has found several very excellent apprenticeship systems, but believes that the best, theoretically, is that mapped out by the Baldwin Locomotive Works. Here the apprentices are graded, the class to which they are assigned depending upon their previous education. As these young men are all under the supervision of an instructor, the results that can be obtained from such a system can but result in furnishing men capable of filling positions connected with the various departments of their works.

This system might not be so important for small shops, but for large concerns, like the Baldwin Works and many of the electrical works, it would be a most excellent thing. For small shops the writer believes the best all-round system to be the regular four-year course, where the boys, in the first place, are taken on trial, and if found satisfactory, indenture papers are made out and fifty or one hundred dollars, as the case may be, are paid for the privlege of their learning a trade. This sum is returned upon completion of the term of apprenticeship, and at the end of the term the young men are also allowed one hundred dollars bonus over and above all wages previously paid to them.

It might not be the wisest plan to hire boys at the very lowest possible price, but to pay them enough to encourage them from year to year; and for the last year they should receive compensation enough to enable them to take care of themselves without any help from their parents or guardians. This, together witht he $150 or $200 paid to them, will be sufficient encouragement to keep them interested.

Finally, a well-designed system, which would insure a proper supervision by competent instructors, and which would include, so far as is possible, some education in mathematics, would, I believe, eventually prove a great help to the many young men who have the ambition to fit themselves for places of trust in the industrial world, as well as to the employers who are constantly seeking for employees to fill these places.

The plan of apprenticeship at the Baldwin Locomotive Works, to which Mr. Parks refers in his article, was worked out by Mr. N. W. Sample, formerly superintendent of motive power of the Denver & Rio Grande Railway. The Baldwin Works employ, at present, about 10,000 men, and with the completion of contemplated extensions of the plant the number is expected soon to reach 12,000.

There always had been apprentices at the works, but with about 90 per cent. piece-work, conducted under a contract system, the boys did not have a fair chance. The results were far from satisfactory, and a systematic method of dealing with the problem of educating "all-around" men seemed to be an absolute necessity. The apprentices now number 750, of whom 115 are indentured under the new plan, which divides them into three classes, and the application blank, reprinted below, indicates in the explanatory note requirements of these classes. Special prominence is given to educational qualifications in the first two classes, while a

third class provides for the shop training of technical school graduates. Of the newly indentured apprentices 70 per cent. are in the first class and 15 per cent. in each of the other classes.

APPRENTICE'S APPLICATION

Burnham, Williams & Co.:

Gentlemen: I desire to become an apprentice in your employ, to learn the trade of.....I was .....years of age at my last birthday, which occurred on the.....day of..... 19.., am sound in body, industrious and intelligent, having attended .....school, and have a knowledge of the following studies, viz:

.....

.....

If my application is considered favourably, I am willing to be indentured for the necessary term of years.

Respectfully yours,

.....

.....

NOTE.—Applications for indenture as first-class apprentices will be considered from boys who have had a good common school education, and are not over seventeen years and three months of age. The compensation for this class is five cents per hour, first year, seven cents per hour, second year, nine cents per hour, third year, and eleven cents per hour, fourth year, with the further sum of $125 at expiration of term of apprenticeship.

Applications for indenture as second-class apprentices will be considered from boys who have had an advanced grammar or high school training, and are not over eighteen years of age. The compensation for this class is seven cents per hour, first year, nine cents per hour, second year, and eleven cents per hour, third year, with the further sum of $100 at expiration of term of apprenticeship.

Applicants for a special course of instruction, covering a period of two years, will be considered from young men over twenty-one years of age, who are graduates of colleges, technical schools or scientific institutes. The compensation for this class is thirteen cents per hour, for the first year, and sixteen cents for the second year.

The usual legal form of indenture is followed for the first two classes. The first class requires four years' service and the age limit is placed so that the boys will finish at the age of twenty-one years. It is expressly stipulated that the apprentice must "faithfully attend at least two evenings in each week during the first three years of his apprenticeship free night schools, such as during the first year will teach him elementary algebra and geometry, and during the remaining two years will teach him the rudiments of mechanical drawing. * * * * It is understood that the apprentice already has a grammar school education, or sufficient to render it unnecessary that any provision should be made for his further instruction."

The second class requires three years' service and requires advanced grammar or high-school training, the upper age limit being eighteen years. During the service the apprentice must "faithfully attend at least two evenings in each week during the first two years of his apprenticeship free night schools which will teach him the rudiments of mechanical drawing."

All three classes are to be moved or changed in the shop, the first two classes every three months and the third class at their own request, subject to the approval of the superintendent. In order to arrange the moving systematically and to keep a complete record of the work, the conduct and character of service of each, a blank form is used, a portion of which, the section for the first year, is reproduced here. These blanks, when completed, contain the record of each apprentice for his entire service, together with every foreman's opinion of him.

BALDWIN LOCOMOTIVE WORKS.

APPRENTICE RECORD.

Name ..... Age..... years..... months.
Address ..... Class.....
Date of Indenture .....19.. Shop.....

FIRST YEAR.

Time.	Expires.	Employed on.	Services were	Conduct.	Rate per hour.	Sig. of Foreman.
1st 3 mos.	.....	.....	.....	.....	.....	.....
2d 3 mos.	.....	.....	.....	.....	.....	.....
3d 3 mos.	.....	.....	.....	.....	.....	.....
4th 3 mos.	.....	.....	.....	.....	.....	.....

REMARKS.

.....

NOTE.—Apprentices will be changed from one machine or job to another once every three months. Apprentices must not be transferred from one department to another without consultation.

While not definitely stipulated, it is understood that the completion of the apprenticeship leaves the company free to offer further employment to all three classes or not, according to the need for men at the time. At this point the personal record is valuable, and it is obvious that if one who has taken the first or second grade has studied faithfully and made his value apparent, he may even pass those of the third or technical class. At least there is nothing to prevent his doing so. It is generally understood that this is a possibility, and that at the end of the training

all apprentices will stand where their records place them.

It is too soon to say what the results will be, but whether it is an ideal system or not, it is a system from which eventually a large number of thoroughly trained young men are looked for. It seems fair to expect that it will produce a large number of good men who are thoroughly imbued with the traditions and spirit of the works.

The apprenticeship system at the works of the Brown & Sharpe Manufacturing Company, at Providence, R. I., as outlined below, has been in use there for more than thirty years, and in almost all cases it has proved very satisfactory. According to the terms of that system, applicants for admission to apprenticeship must be not less than sixteen nor more than eighteen years of age. They must be physically sound, of good moral character, and have received an education equivalent at least to that required for graduation from the public grammar schools of the city of Providence. Application must be made in person, and, if accepted, the applicant's name will be registered and due notice given when he will be required to commence work.

The first four hundred and eighty hours of service shall constitute a term of trial. If the apprentice shall, during this term, prove satisfactory, and shall, before the expiration thereof, execute, together with his father or guardian,—or if he have no father or guardian, then with some other responsible party,—an agreement in the form given below, then his apprenticeship shall continue for the full term, unless sooner terminated as stated later.

AGREEMENT made this ..... day of ..... A. D. 1...., between the Brown & Sharpe Manufacturing Company, a corporation established in the city of providence, in the State of Rhode Island, party of the first part; ..... of ....., party of the second part; and..... of ..... party of the third part.

WHEREAS the party of the second part is desirous of becoming an apprentice to the party of the first part, for the purpose of acquiring the art or trade of machinist.

NOW THIS AGREEMENT WITNESSETH:

That the party of the first part, in consideration of the covenants herein contained on the part of the party of the third part, hereby accepts the party of the second part as an apprentice in the art or trade of machinist, subject to and in accordance with the "Terms of Apprenticeship" which are hereto annexed and made part hereof.

The party of the second part, in consideration of such acceptance, hereby agrees to become the apprentice of the party of the first part in the machinist's art or trade, in accordance with the said "Terms of Apprenticeship," and to faithfully conform to the provisions thereof.

The party of the third part, in consideration of the covenants on the part of the party of the first part herein contained, for himself, his heirs, executors and administrators, covenants with the party of the first part, that he will pay the party of the first part as compenstion for receiving the party of the second part as an apprentice, the sum of fifty dollars ($50.00)—said sum to be paid at the expiration of the term of trial referred to in said "Terms of Apprenticeship."

The party of the third part, for himself, his heirs, executors and administrators, covenants and agrees, to and with the party of the first part, that the party of the second part shall well and truly conform to and abide by all the provisions of said "Terms of Apprenticeship" and of this agreement.

The party of the first part covenants and agrees, in case the party of the second part shall serve the full term of said apprenticeship (including the making up of lost time), as provided in said "Terms of Apprenticeship," and shall in all respects comply with the provisions of said "Terms of Apprenticeship," to pay to the party of the second part, at the termination of said term of apprenticeship, in consideration of such faithful service, the sum of one hundred and fifty dollars ($150.00).

IN WITNESS WHEREOF, the parties hereto have hereunto set their hands and seals (the party of the first part by.....its.....duly authorized for that purpose), the day and year first above written.

Executed
in the presence of

.....

.....

.....

Apprentices will be required to serve for the term of four years,—each year to consist of two thousand nine hundred and fifty working hours, which, with the usual working day of ten hours each, are equal to two hundred and ninety-five working days. The remaining working days in each year will be allowed apprentices for recreation, at such time or times as the company shall direct.

Graduates of the Providence Manual Training High School, well recommended by the principal, may have their term of apprenticeship shortened at the discretion of the company.

Apprentices will be required to perform their duties with punctuality, diligence and fidelity, and to conform to the rules and regulations which are or may be adopted for the government of the shops. Apprentices are not allowed to use tobacco in the shops during working hours.

Apprentices shall make up lost time at the expiration of each year, at the rate of wages paid during that year, and no year of service shall commence until the apprentice shall have fully made up all time lost in the preceding year.

The company reserves the right, whenever the state of business dema ıds it, to shorten the hours of labour, or whenever for any reason it shall stop the works, to suspend apprentices wholly or in part; and the making up of time so lost shall be at the discretion of the company.

The company also reserves the right, in its sole discretion, to terminate its agreement with any apprentice, also to discharge him from its employment for non-conformity with its rules and regulations, want of industry or capacity, indifference to his duties or improper conduct within or without the shops.

Apprentices will be paid for each hour of actual service (not including time allowed for recreation or time when work is suspended) the following wages: —for the first year, six cents; for the second year, eight cents; for the third year, ten cents; and for the fourth year, fourteen cents. If the company shall terminate the apprenticeship during the time of trial, it will pay at the rate of six cents per hour for the time worked.

Wages will be paid on the regular pay-days of the company, as they may be established from time to time.

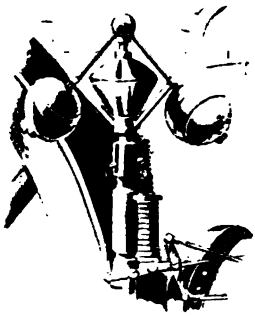
The company will faithfully instruct the apprentice in the machinist's art and trade, in their shops, during the term of apprenticeship.

TRAINING APPRENTICES

IN THE ROYAL DOCKYARDS OF GREAT BRITAIN

By Frank Barter, M. Inst. N. A.

Mr. Barter's account of the method of training apprentices in the government dockyards of Great Britain is an appropriate supplement to what is told in the preceding article, of apprenticeship systems in the United States. It is reprinted from an earlier issue of this magazine, having been revised and partly re-written for this purpose by the author.—THE EDITOR.



THE alleged decline of industrial supremacy has in recent years engaged the anxious attention of the people of Great Britain, and her foreign competitors have derived considerable satisfaction from the existence of such a belief. Two reasons have been persistently advanced as mainly contributory to this state of affairs, namely, the evil influences of misguided trades unionism and the faulty methods practised in educating the workers in technical matters. Perhaps it would have been more correct to say the absence of any method at all.

Trades unionism the writer will not discuss here, but will endeavour to deal briefly with the existing methods of training apprentices in two of the most prominent of Britain's industries,—shipbuilding and engineering,—and with the system of education adopted by the British Admiralty for the apprentices of the Royal Dockyards, and to contrast this latter with what is done by private employers for their apprentices.

The fundamental conditions which govern the two classes of apprentices are, of course, very different in character. Broadly speaking, we may put it thus:—In the private shipyard or engineering works the apprentice is regarded by his employers mainly in the light of a profit producer, and in return for his services as such he is permitted to learn the business up to the point of making a workman of himself. In the royal dockyard, on the other hand, the apprentice is regarded in the light of a student as well as a "trade" apprentice, and he is educated by the government in both senses. Practically unlimited facilities are afforded him for the acquisition of the most useful education obtainable,—scholastic as well as technical,—the object and hope of the Admiralty being, of course, that they will be able to retain in their service those who have benefited most by such facilities.

The proprietors of private establishments cannot, seemingly, afford to do much more than train their apprentices to become good workmen. Even the additional advantages enjoyed by what are called "premium" apprentices are usually of a merely departmental character (that is to say, the privilege of "going through" the various departments), while the young men are left pretty much to their own resources and inclinations in the pursuit of purely educational studies.

Having thus broadly indicated the distinctive circumstances which govern the training and education of the two classes of apprentices, let us study the matter somewhat more in detail. To begin with the apprentices of private establishments, the boy whose parents cannot afford to pay a premium has little chance, in the great majority of

cases, of learning the entire art of shipbuilding, for example, but must of necessity be content to select one of the many "trades" into which that industry is divided,—that is to say, he must decide to become either a ship carpenter, or a boatbuilder, or a plater, or an anglesmith, or a loftsman. If he have a fair knowledge of elementary mathematics and a liking for drawing, he may, perhaps, wish to become a draughtsman, but even in this department he is sometimes called upon to pay a small premium.

On the other hand, the boy who desires to become a shipbuilder in its broadest sense must spend a portion of his apprenticeship in each of the several departments or "trades" already enumerated; but, in the great majority of cases, a heavy premium has to be paid for such facilities, varying from £50 to as much as £750.

The same circumstances usually prevail in the engine department. The boy who wishes to learn engineering in its complete sense must pay a premium. If his parents cannot do this he must decide to become either an engine-fitter or a turner, a pattern-maker, a boilermaker, a coppersmith, or perhaps a draughtsman.

It is not proposed here to enter into a discussion of the ethics of premium-paying, because it is not strictly within the limits of the subject under review. As already intimated, however, whether a premium has been paid or not, the proprietor of a private establishment, in the great majority of cases, fulfills his contract with his apprentice by teaching him (perhaps I should rather say,—allowing him to pick up) the purely practical or mechanical part of his business, and undertakes no responsibility for his training in technical studies which are indispensably a part of the complete education of the practical shipbuilder or engineer.

Now let us turn to the apprentices of the Royal Dockyards! At the outset it should be explained that the Admiralty exacts no premiums, but a civil service examination, preceded by a medical examination, has to be passed in the following subjects before a boy can be received into a government dockyard:—

Arithmetic.—The whole of the subject usually taught in public schools, except cube root.

Orthography.—Two selected pieces of dictation, to be done in a given time.

Handwriting.—Usually a paragraph containing a tabular statement of statistics.

Geography.—Of the world, particularly of Great Britain and her colonies.

English.—Including analysis, syntax, etymology, etc.

English Composition.—Moderate proficiency.

Algebra.—Up to and including simultaneous and quadratic equations.

Geometry.—Books I., II. and III. of Euclid, with deductions thereon.

Arithmetic, orthography, and handwriting are compulsory subjects, the others being optional; but perhaps I need hardly say that the candidate who takes only the "compulsory" subjects never gets in. Every successful candidate is given the choice of his profession according to his position on the merit list, and, upon appointment, receives an instructor, whose special duty is to guide and instruct him in the purely mechanical operations of his business,—shipbuilding or engineering, as the case may be. These instructors are (or, rather, should be) skilled workmen of good character, who are selected by the superior officers of the dockyard, and receive an extra two shillings a week for the first four years of the lad's apprenticeship.

Each apprentice is bound by an indenture of a rather elaborate character to serve for six years "after the manner of an apprentice, for the use and benefit of His Majesty, His Heirs, and Successors." He further binds himself not to absent himself from service without leave, "nor contract marriage during the period of his indenture, nor be guilty by word or action of any immoral, indecent, irregular, or improper conduct or behaviour in any respect whatsoever, but shall and will demean himself at all times with strict propriety

and submission to his superiors." The father or guardian of the apprentice binds himself in the same indenture to " provide good and sufficient board, lodging, clothing, washing, and other necessaries proper for his personal accommodation and benefit, and suitable to his intended situation; and also all such implements, working tools, and instruments as shall be requisite to enable him to learn and practise his art."

These quotations may not, perhaps, be considered strictly relevant to the subject under review, but their introduction at this stage may interest those who are unacquainted with the terms of " indentures of apprenticeship."

I propose first to explain the nature of the practical training given to the government apprentice. It will be inferred from my previous remarks that the apprentice enjoys the constant companionship of his " instructor " for the first four years of his apprenticeship, after which he is expected to work as a " mate " with any mechanic to whom his inspector may appoint him. In the shipbuilding department the apprentice is afforded facilities for acquiring an intimate knowledge of all the operations of construction, from the preparation of the blocks for receiving the keel to the finished sea-going condition of a ship. He is taught to prepare and erect the framework of the vessel, to template and fit in place the steel plating of shell, decks, and watertight compartments, and to test these compartments. He learns how to make and fit watertight doors and their appliances, sluice valves, in fact, all the work involved in fitting out a ship with pumping, flooding, draining, and ventilating arrangements, except such work as legitimately belongs to the coppersmith, or blacksmith, or moulder. It will thus be seen that the young shipbuilder acquires an intimate knowledge of the treatment of steel and ironwork, and skill in the use of the appropriate tools.

The various operations and details of work which have so far been enumerated collectively constitute the art of building a modern steel ship; and remembering that this work in private shipyards is divided amongst several classes of skilled workmen, as framers, platers, loftsmen, fitters, etc., it is manifest that the modern dockyard apprentice has a much wider scope for the exercise of his energies than the private yard apprentice.

It should not be inferred, however, that the present-day dockyard apprentice is not a woodworker as well as a metalworker. That is by no means the case, for he has to make himself proficient in all the woodwork usually done by ship carpenters in private establishments. That is to say, he is taught to prepare and lay deck planking, to fit up storerooms and magazines, launching arrangements, etc., and occasionally to build composite vessels.

The practical operations of dry-dock ing and undocking ships, and general repair work both in dock and afloat, constitute another important branch of his training.

Up to a few years ago the dockyard apprentice received twelve months' training in the ship-fitter's, or millwright's, shop, where he was taught to use the lathe, slotting and planing machines, and engineering tools generally; but this has now been discontinued, presumably in consequence of the militant attitude of modern trades unionism. The term of apprenticeship has also been reduced from seven to six years.

So much, then, for the training given in the practical work of the shipyard. In addition to this, facilities are provided for instruction in ship-drawing. Evening classes are conducted in the dockyard drawing offices by the chief draughtsman, who receives additional remuneration for such special duty, but attendance at these classes is quite optional. Those who attend the class for a year are selected by rotation for six months' day instruction in the drawing offices and mould loft, where they are taught to prepare the simpler working drawings and tracings, ordering materials, and all those interesting geometrical problems involved in " fairing the body " and " laying off " the parts of a new design. This period of instruction usually comes during the

fourth or fifth year of apprenticeship. Certain of the apprentices, however, receive twelve months' day instruction in drawing, to which further reference will be made later.

Apprentices who display a special aptitude for drawing are sometimes retained in the drawing office (or "borne out on drawing duties," as it is termed), and receive appointments as draughtsmen as vacancies arise or the exigencies of the service demand, after passing the necessary competitive examination in practical and theoretical naval architecture.

The apprentices in the engineering department are given facilities similar to those in the shipbuilding department for the acquisition of a thorough knowledge of their business, and every such apprentice likewise receives an "instructor." I am not so intimately acquainted with the practical training of apprentices in the engineering shops as with those of the shipyard, but I think I am correct in saying that all apprentices spend some part of their apprenticeship in the turning shop, erecting shed, pattern-maker's shop, boiler shop, iron foundry, brass foundry, coppersmith's shop, and "finishing" shop. Their instruction in drawing is precisely similar to that given to shipyard apprentices. Some of the apprentices get opportunities for working in the "torpedo" shop, and in the "ordnance" department, although apprentices generally cannot claim such facilities by right.

As to the purely educational training provided for dockyard apprentices, each of the five dockyards has a training school with a library attached. The school is divided into two classes,—an "Upper Division," for apprentices in their third and fourth years, and a "Lower Division," for first and second year apprentices. Each division attends school two afternoons and evenings a week for general ssudy, and on Wednesday evenings for laboratory experiments and science lectures. All text-books are supplied by the Admiralty, and include the best standard works on professional subjects. Examinations, lasting from three to six days, are held every six months, and the results are published in the order of merit. Apprentices who do not obtain a specified percentage of the maximum marks, or whose conduct or diligence is not satisfactorily reported upon, are not permitted to continue at school. Consequently there is an annual weeding out of deficient ones.

The greater number of apprentices leave school at the end of their third year, and some have to leave at the end of their second, or even their first year. Those of special merit remain at school during their fourth year, and are attached to the drawing office for twelve months, that is, during the whole of their fourth year, under the guidance of a draughtsman "instructor." At the end of this time they are examined in the subjects of the "Upper Division" course of study, which will be referred to further on.

Usually the best two or three apprentices on the fourth year list then proceed to the Royal Naval Engineering College, at Devonport, to continue study during their fifth year, either as "students of naval construction" or as "engineer students," according as they are in the shipbuilding or engineering department.

The subjects of examination for apprentices in the "Lower Division" (first and second year apprentices) are:—

Arithemetic and mensuration	400	mks.
Algebra	400	"
Geometry (Euclid's Books I. to VI., XI. and XII., with deductions)	500	"
Trigonometry	500	"
Statics and hydrostatics	600	"
Physics (light, heat, magnetism and electricity)	600	"
Chemistry	500	"
French (optional)	400	"
Geography and English history	400	"
Total	4,100	"

First-year apprentices must obtain at least 40 per cent. of this total to be permitted to attend school during their second year. Second year apprentices must obtain at least 60 per cent. to be permitted to continue during their third year, when they become "Upper Division" students. The subjects of examination for the "Upper Division" are: –

Statics, hydrostatics and hydraulics	500	mks.
Dynamics	500	"
Applied mechanics	500	"
Higher algebra and trigonometry and elementary conic sections	500	"
Differential and integral calculus and conic sections	700	"
Descriptive geometry (*or* mechanism)	400	"
Physics (light, heat, magnetism and electricity)	700	"
Chemistry	400	"
Naval architecture (*or* engineering)	2,400	"
Total	6,600	"

A third-year apprentice must obtain at least 40 per cent. of this total to continue study during his fourth year, and, as before remarked, the best two or three of the fourth-year apprentices proceed to the engineering college at Devonport to continue study during their fifth year. A fifth-year apprentice will be either nineteen or twenty years of age, and the final examination at the end of the fifth year is of a very difficult character, as will be seen from the list of subjects below. There can be no two opinions as to the intellectual brilliance of those apprentices who can pass a satisfactory examination in such a list of advanced subjects. They are:—

General paper in elementary mathematics and mensuration	500	mks.
Statics, hydrostatics and hydraulics	500	"
Dynamics	500	"
Chemistry	400	"
Physics ([*a*] heat and light; [*b*] magnetism and electricity)	700	"
Applied mechanics and graphical statics	500	"
Descriptive geometry	400	"
Advanced algebra and trigonometry	500	"
Conic sections, and differential and integral calculus	700	"
Practical physics	300	"
Heat, combustion and metallurgy	800	"
Practical Shipbuilding—Part I.	1,000	"
" " Part II.	1,000	"
Shipyard machinery—Practice and appliances	600	"
Ship drawing	600	"
Laying off and mould practice	1,000	"
Total	10,000	"

In the place of descriptive geometry and the last five subjects of this list, engineer students take:—

Theory of mechanism and machinery.
Steam and the steam engine.
Practical engineering.
Workshop appliances and practice.
Mechanical drawing.
Design of machinery.

Those who pass this examination satisfactorily proceed to the Royal Naval College, at Greenwich, to continue their studies in the above-named subjects, with the addition of papers on " theory of waves and propulsion," and " stability and oscillation of ships."

Apprentices who obtain at least 75 per cent. of the maximum marks in the " Upper Division " examination are permitted to retain their books on the completion of their school course, and as the full " Upper Division " course of study requires between forty and fifty text-books, worth from £15 to £20, it is evident that they are worth working for. Less than 10 per cent. of the apprentices, however, reach this standard.

Prizes are awarded annually by the Lords of the Admiralty to the most distinguished apprentices in each division, the first prize in each division being known as the Admiralty prize. All apprentices attending school are granted three days' holiday after the summer examinations. Fourth-year apprentices (*i. e.*, those who have taken the final " Upper Division " examination) get a week's leave.

It will thus be seen that the educational training provided for the apprentices of the Royal Dockyards is as thorough as the practical, and it is also clear that apprentices who wish to get on, can and do get on.

It might appear to some that the lad who " goes through " such a wide and varied course of training as has been here set forth must be a sort of " Jack of all trades, and master of none," or that he will be either a good scholar or a good mechanic. It should be remembered, however, that whereas the term of apprenticeship in private establishments is limited almost universally to five years (and in some districts to only four years), the dockyard apprentice serves six years, and until recently served seven years; and it should also be borne in mind that most lads of ordinary intelligence will learn more of their business during their fifth and sixth years than during their first, second, third, and fourth years put together.

The writer, who was in the Admiralty service for nine years, and has since been for several years in daily intercourse with private establishments, can testify to the superior " all-round " fitness of dockyard trained workmen, as

compared with men who have been trained in private establishments. Furthermore, the highest professional positions in the country are held by men who receive their training in the Royal Dockyards; for example, the higher positions of the Admiralty, the marine department of the Board of Trade, Lloyd's Registration Society, and of many of the leading private shipbuilding and engineering establishments. The current standard works on professional subjects have nearly all been written by dockyard trained men,—Sir William H. White, for example, Sir Edward J. Reed, Messrs. Thearle, Sennett, Seaton, Welch, and others.

The provision of such a training for the apprentices of private establishments seems nowadays to be impracticable on account of the expense which it would entail. To some extent this difficulty is met by the Department of Science and Art, South Kensington (or the "Board of Education," as it is now called), which encourages the establishment of evening classes in science, art, and technology, and of which a large number of apprentices (both dockyard and private) take advantage.

It is a very regrettable circumstance, however, that the proprietors of private shipbuilding and engineering establishments of Great Britain, speaking generally, take little interest in the technical education of their apprentices. I say speaking generally, because there are a few singularly conspicuous exceptions. The most notable case which occurs to me at the moment is that of Messrs. William Denny & Brothers, of Dumbarton. The evening classes in science and art at Dumbarton are largely subsidised by the members of this world-famed firm, who take a fatherly interest in the intellectual welfare of their apprentices, akin to that which they are known to take in the moral and social welfare of all their employees. All apprentices are encouraged to usefully employ their evenings by attending the local classes in science and art. The fees are merely nominal, and are returned to those who attend regularly and pass their examinations. Messrs. Denny have established a well-stocked library of scientific works in connection with their shipyard drawing office, open to all their draughtsmen.

They refuse premiums, preferring apprentices with brains rather than money. Those apprentices who wish to enter the drawing office with the view of becoming draughtsmen are expected first to serve about two years in the shipyard, should have passed the elementary stage of naval architecture, and must be of good character. Every apprentice in the drawing office of the shipbuilding department is given, as far as practicable, a year in what is called the "Scientific Department."

The writer had the honour of serving Messrs. Denny in this department some years since, and, coming to them direct from a government dockyard, could not fail to be struck with admiration at the atmosphere of smartness and loyalty which pervaded all departments of this great establishment, and in this respect Messrs. Denny, doubtless, consider themselves well repaid for their interest and encouragement. There are a few other important firms in the country who are known to emulate this example, though by no means to the same extent.

While shipbuilders and engineers cannot be expected, generally speaking, to put themselves to the expense of educating their apprentices as thoroughly as the Admiralty do, there is certainly nothing impracticable about the example set by Messrs. Denny & Brothers, an example which is a very creditable distance from the absolute indifference which too generally characterises British employers with respect to the technical education of their apprentices. There is no doubt that much of the existing pessimism as to loss of commercial prestige with which Great Britain seems to be threatened would be removed if shipbuilders and engineers would take more interest in the intellectual welfare of their apprentices, or, for that matter, their employees generally. When this happens, employers will find it as much to their profit as to their credit.

THE TREND OF MACHINE TOOL DESIGN

By Joseph Horner

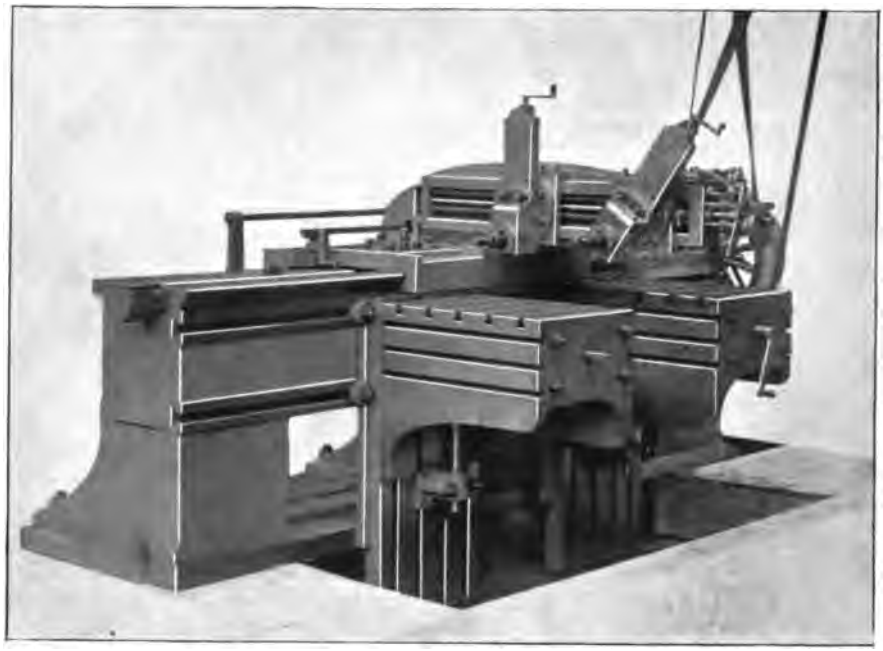
THE belief that machine design and construction have reached, or nearly reached, their limits, is one which cannot be entertained by any, except those of ultra conservative views. It might seem bold, on the other hand, to affirm that machine tool design is as yet only in an early stage. But the latter prediction would be more in accord with probability than the former. It is certain that some of the developments of the present period would have been treated as entirely Utopian twenty-five years ago. Yet large numbers of the machines of that time are now obsolete, and the same fate will almost certainly have overtaken some of the best machines of to-day when another generation arrives on the busy scene.

It may not, therefore, be uninteresting or unprofitable to consider briefly the probable directions in which improvements and developments may be expected to take place, though this may seem like idle predictions of the oracle or soothsayer; yet if we confine our forecasts to the finger post of obvious facts, that should redeem them from the imputation of charlatanism.

The old-fashioned engineer who has been working, and is still working, with tools laid down thirty or forty years ago,—tools "practically as good as ever,"—has been having an uncomfortable time of late. Some of the good old tools are as capable as ever, and though little readjustments and corrections have been made in them at intervals of a few years to compensate for wear, there is no reason why they should not last well into the present century; in fact, it is difficult to see how they can ever become worn out. And yet many of those tools are really of little more value than the mere metal in them, because machine shop practice has been changed so profoundly by the growth of new ones.

Yet if a firm decides on remodelling its ways, dismissing the good old servants and replacing them with more capable ones, the difficulties encountered are still great, because it is clear to anyone who gives the matter much thought that machine shop practice is now in rapid transition; that the very best modern tools may, and will in all likelihood, be superannuated in the course of the next few years; that, in fact, the newer tools have a very much shorter expectation of life than their patriarchial predecessors had.

Though it is unsafe to indulge in much precise prophecy, it is not difficult to observe the broad trend of modern machine tool design from a consideration of the conditions which have arisen during recent years, and by noting the types of tools which have been advancing in favour of late. But if we attempt to find the most convenient standpoint from which to regard this subject, we meet with another difficulty, because the practical aspects of the question vary so much with the conditions in individual shops. We may best consider the subject in the first place from the points of view of the shops that handle specialities only or chiefly, and of those which deal with a miscellaneous class of work,—the general shops; and this appears to be the proper way to approach the problem, because the methods of each are very



A SIDE PLANING MACHINE WITH TWO TOOL BOXES ON THE ARM, MADE BY MESSRS. GEORGE RICHARDS & CO., LTD., BROADHEAD, NEAR MANCHESTER, ENGLAND

largely, in many cases absolutely, controlled by these broad differences. But outside of these again there are certain developments that have come in by a natural, inevitable growth, and which affect all machine tools,—such as styles of building and numerous details of construction that result from a higher mechanical ideal than that which formerly prevailed. It would be interesting also to compare the developments in details of the designs of the various types of machine tools; but this would demand many articles.

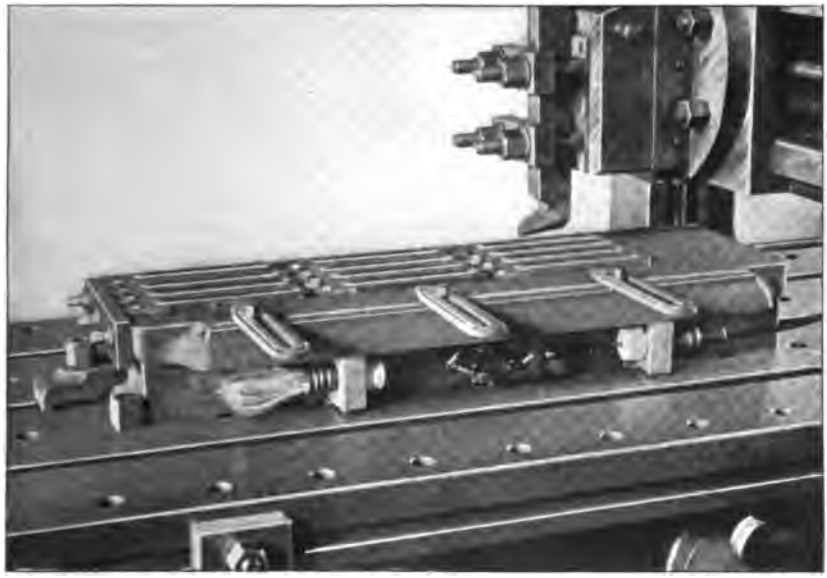
Since the trend of engineering and machine shop practice during a generation past has been steadily in the direction of increased specialisation, the designs of machine tools have been correspondingly specialised; and this is, perhaps, the most obvious and striking feature in the modern trend. Those who were trained in the firms of, say, twenty-five or thirty years ago, see how vast is this change. Then, all engineers, with scarcely any exceptions, manufactured anything that was included in, or related to, a very extensive class of work, the only limitations which were imposed being those of capacity and of producing power. Many shops did not even confine themselves to any broad class of work, but tendered for whatever offered, whether engines, cranes, pumps, cocks, valves, waterwheels, gas-making plant, pipes, gear wheels, water tanks, penstocks, boiler fittings, machine tools, and so forth. This is no imaginary list, for the writer has himself had experience with all these, and more, in one firm.

But the old general shops of this type have gradually narrowed the sphere of their once diffuse energies, finding themselves unable to compete with new firms who have from time to time laid themselves out for the manufacture of specialities of some one or more of these articles. First one branch then another has been dropped, and when goods have been wanted to fill up an indent the general firms have gone to the special ones and purchased them, or have sublet their contracts. The new

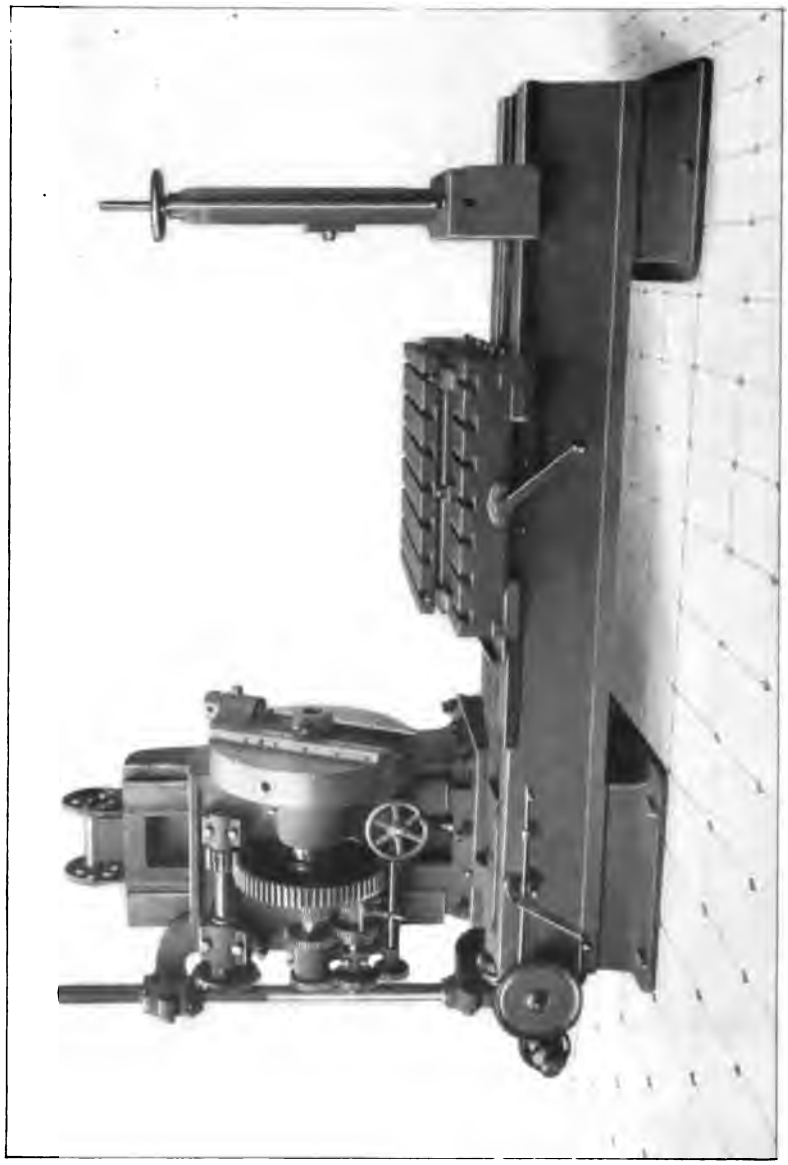
firms that have arisen have not, as a rule, attempted such a general run of work, but have commenced with the manufacture of a single class of goods, thus beginning at that stage at which the older ones are arriving or which they have reached. The result is that the newer shops have laid down plant that is directly correlated to the class of work which they have undertaken; while the older ones are greatly hampered with a plant designed for general practice, and by which they are placed at much disadvantage with regard to facilities for economical production with their younger competitors.

The radical character of this profound change hardly seems to be yet grasped by the general manufacturer. With this growth of specialisation the machines not only have been, but will become, more highly differentiated. In the general shop we have numerous examples of tools which combine several functions, as milling and gear cutting, planing and milling, drilling and boring, turning, boring, and surfacing, *e. g.*, lathes having both long beds and gaps, to cover an exceedingly wide range of work both in length and diameter. In the multiple-spindle drills and in duplex boring machines we have spindles adjustable for varying centres, both being concessions to the general shops. There are also the universal machines for milling, for gear cutting, grinding, etc.

But when thousands of pieces, the shapes of which are identical and fixed with reasonable permanence in all their details, have to be manufactured for years in succession, then machines are designed to operate on certain pieces only, and thus we get the gear cutter that shapes one particular class of wheel, as spur, bevel, or worm only; the milling machine that deals with one product, long or short; the plain machine, or that in which the universal head is the predominant feature. Drilling, again, is done on machines in which no provision is made for boring; the functions of boring and turning are done on separate lathes; the turning of small diameters on work of great length is done on lathes in which more than one tool comes into operation; and surfacing is performed on another class of lathe in which work of considerable



A MAGNETIC PLANER CHUCK MADE BY MESSRS. O. S. WALKER & CO., WORCESTER, MASS., U. S. A.



UNIVERSAL BORING, FACING, AND MILLING MACHINE MADE BY MESSRS. FRANK PEARN & CO., LTD., WEST GORTON, MANCHESTER ENGLAND

length cannot be put. Turning and milling are relegated to distinct machines; multiple-spindle drills have their centres fixed, *e. g.*, for the drilling of several machine framings or parts of a certain size, and so, too, we have duplex boring machines with fixed centres for the simultaneous boring of double cylinders for engines and pumps, and for electric motor casings. The fully automatic screw machines are among the most familiar examples of tools that are of little use in a general shop, but which are the most valuable aids in the work of those who handle specialties of almost any class. The relieving lathes are of no value, except in shops where a large number of cutters are made. The high-class universal grinders presuppose the employment of milling cutters to a large extent and a rather extensive practice in grinding various pieces of work. Then there are such machines as axle-turning, tire-turning, wheel-turning lathes, of highest value in railway and waggon works. Supplementary machines for centring and facing bars, for cutting off bars, the shaving lathes, and others are examples of a similar character. The employment of these acts and reacts economically on their product, since their introduction is followed inevitably and constantly by extensions of their utilities.

In the course of time the great majority of machine tools will, it is safe to predict, become segregated and crystallised into certain very highly specialised types. Each type will be the well-known speciality of a certain firm, or of but a very limited number of firms, and these tools will become as well known as, say, a Jones & Lamson lathe, or a Brown & Sharpe or a Landis grinder, or a Bullard vertical mill, or a Spencer, or a Hartford, or a Herbert automatic screw machine is to-day. Everything appears to indicate that the broad trend is in that direction, and the earlier manufacturers fully recognise this probability, the better will they be prepared to enter into the severe competition of the coming years. It does not require much prescience either to apprehend that we are only now at an early stage of this differentiation in the practice of firms. The time must inevitably arrive when instead of a very few firms, as at present, nearly all will be compelled by stress of circumstances to confine their energies to the construction of one class of mechanism, made in only a few sizes. There are many advantages in the adoption of such a practice.

A TURRET HEAD BORING AND TURNING MACHINE BUILT BY MESSRS. GEO. RICHARDS & CO., LTD., BROADHEATH, MANCHESTER, ENGLAND

A question arises out of this:—If the work of the general shop is doomed to such redistribution, what of the jobbing work and the repairs that are so necessary and profitable at present? The answer is that the first will, doubtless, continue to engage small firms and will form a separate department of the larger ones, as now. But the necessity for repairs is becoming of lessening importance, since one valuable result of abso-

AN AUTOMATIC NUT TAPPER MADE BY THE ACME MACHINERY CO., CLEVELAND, OHIO, U. S. A. THERE ARE FOUR VERTICAL TAPPING SPINDLES, DRIVEN BY GEARING. THE NUT BLANKS ARE PLACED IN THE CIRCULAR RECEPTACLE AT THE TOP, FROM WHICH THEY FIND THEIR WAY, BY CENTRIFUGAL FORCE, TO THE FOUR CHUTES LEADING TO THE TAPS

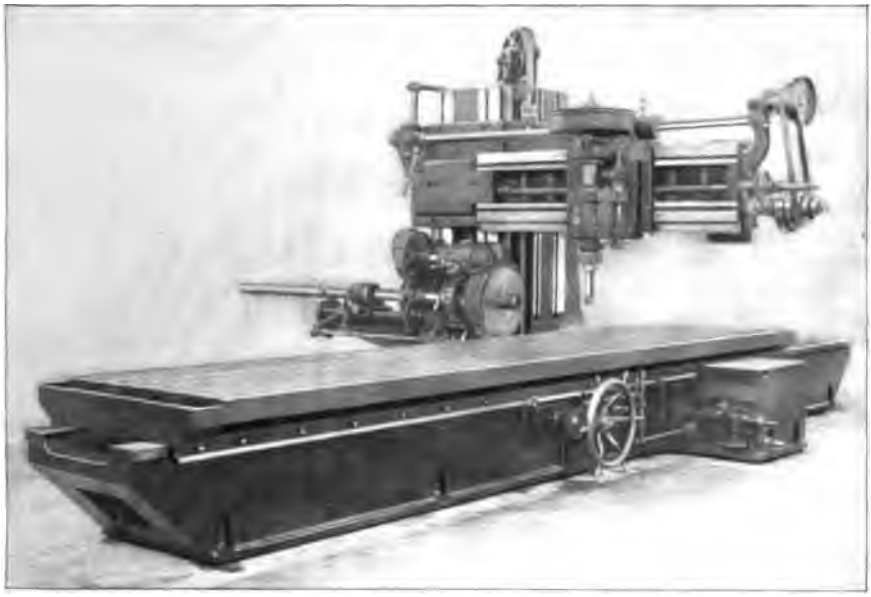
lute specialisation is that replace parts, which require no fitting or fudging, can be sent on receipt of letter or telegram, thanks to the facilities afforded by the mperative economical necessity for the use of jigs and templets.

The inevitable trend of machine tool design, apart from this growth of specialisation of engineers' work, has been, and still is, towards increased power, capacity, portability, handiness, and also excellence of workmanship. Increase in power is a development that has always been in evidence, though more pronounced in recent years than at earlier periods. An oft-quoted illustration is the difference between the boxed and the ribbed framings, but there are others. This growth is less apparent in the common lathe than in other machines, notably the automatics and milling machines.

The Manchester lathes of forty years ago were more solid than the American

ones of to-day are, and little advance has been made in Great Britain during more than a generation. The old beds, headstocks and sliding surfaces compare favourably with those manufactured to-day. The chief improvements in later types have been in greater length of spindle necks and in the width of the steps of the belt cones. In many of the newer lathes and in their allied forms the employment of the hollow spindle has had the result of increasing the bearing surfaces of necks, while the heads are built of massive design to resist the heavy stress of cutting with broad forming tools on cross slides and on turrets. A similar increase in mass is visible on the later turrets, turret bases, and slides, which are models of strength and stability, and the value of the pillar of semicircular section. In the average planing machine the parabolic housings are stiffer, as well as more handsome than the old triangular brackets. Shapers are built stiffer, and milling machines and gear cutters are now exceptionally rigid by comparison with earlier ones. In most machines, too, wider belts are used than formerly, and larger wearing surfaces are provided.

One of the troubles incidental to the working of machine tools is chatter. The principal cause of this is to be sought in weak framings and spindles. But this evil is not now so serious as it was formerly, because manufacturers have put increased weight into their machines, and also have learned where to place the added metal to the best advantage in the more vital portions.



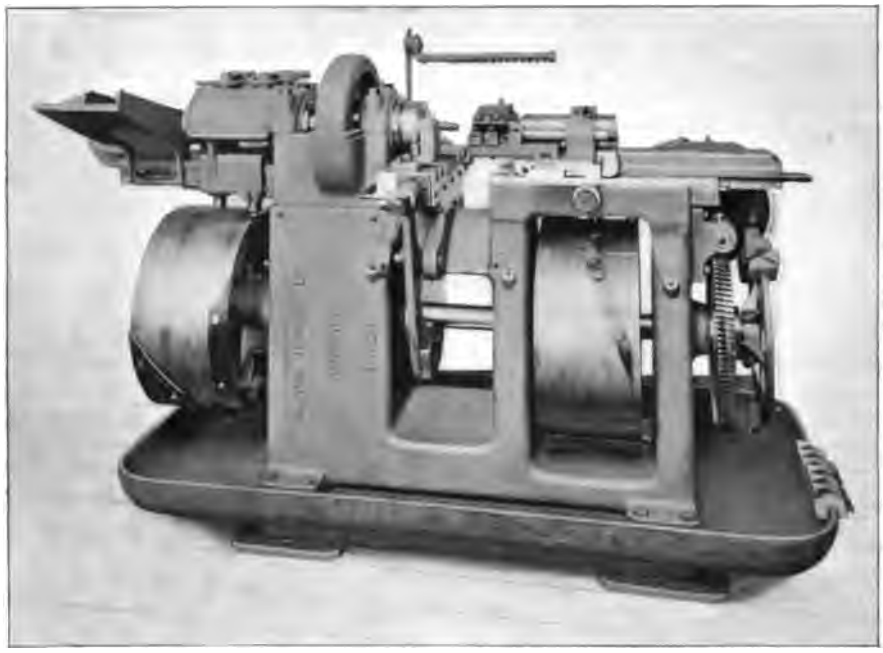
A VERTICAL MILLING AND HORIZONTAL BORING MACHINE MADE BY J. E. REINECKER, CHEMNITZ-GABLENZ, GERMANY

these designs is exercising a more powerful influence in the remodelling of other and older tools.

In radial drilling machines the circular pillar and the parabolic arm contrast favourably with the old type, in which a light arm was cast in one piece with

Since the demand is ever increasing for machines that will remove greater quantities of metal in a given time without chatter, it is certain that increase in weight must still go on.

It is hardly conceivable that any manufacturer should think it worth his while



AUTOMATIC SCREW MACHINE WITH MAGAZINE FEED. MADE BY ALFRED HERBERT, LTD. COVENTRY, ENGLAND. THIS MACHINE HAS NO TURRET, BUT A SLIDE

to risk the reputation of a machine for the sake of skimping a few hundredweights of cast iron. Yet improvement here has been very slow, very tentative, a creeping up by minute improvements, as if in fear of doing too much in that way at once, the "extra heavy," "extra broad," "extra large," "extra strong" of the catalogues denoting nothing definite and tangible.

Yet how essential rigidity is, is illustrated by the milling machine especially, which has a greater tendency to chatter than any other tool. It met with little favour until manufacturers learned to lump the metal in framings and spindles. Several of the leading live firms fully recognise the importance of mass, and their recent designs leave nothing to be desired, because the metal is concentrated in the most vital parts, and the bearing surfaces are increased, with corresponding increase in capacity and steadiness under the severest tests. To this also must all machine tool design tend in the coming years. Firms whose products are not now in line with modern requirements will have to get abreast of these demands or go out of the running, while the leading ones will still continue, as at present, to bring out improved designs from time to time.

Increase in capacity has been a feature of recent rapid growth, and its extension is inevitable. There were a few big machines in the old days, but for one big machine then there are scores now. This has been made necessary by the increasing dimensions of modern engines, dynamos, machine tools and other structures; but it has largely followed on the introduction of mild steel, because this is cast and forged in masses immensely larger than iron ever was. Guns, crank and propeller shafts, big boiler plates and boilers demand machines of greater capacity than heretofore, and this is a development of which we have not yet seen the end. Another reason lies in the practice of casting various parts in one piece instead of fitting them separately; another, in the tooling of several sections simultaneously on one machine instead of shifting

the work to two or more machines. Portability is another valuable characteristic, the trend of which in some modern machines is unmistakable, and which is destined to grow in favour. As work increases in size, it often becomes easier to bring the machine to the work than to adopt the older reverse process. The most common example of this kind is also the oldest,—the portable drilling machine. From a very small affair it has grown into massive types, many of which are now too heavy to be carried to the work in the ordinary way, and have, therefore, to be transported on wheels. In some of these machines the arm is of the radial type, and the head has a universal movement. The value of such machines as time-savers is very great, since often the only alternative is hand drilling with a ratchet brace. Machines of this class are now most conveniently driven electrically, and there is, therefore, no limit to the distance over which they can be transported from their source of power.

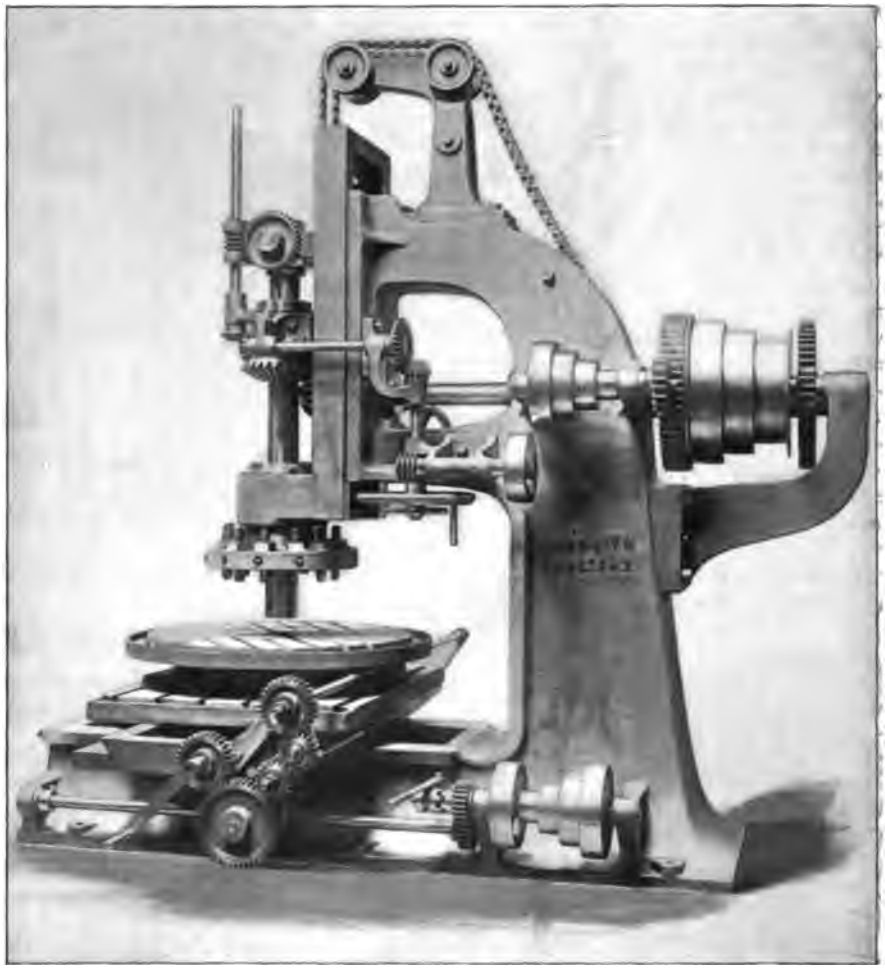
A BOX TOOL WITH THREE CUTTERS FOR TAPERING THE END OF A BAR IN READINESS FOR OTHER BOX TOOLS TO COMMENCE OPERATIONS. MADE BY ALFRED HERBERT, LTD., COVENTRY, ENGLAND

The portable key seaters furnish another recent example of this trend. Chipping and filing key grooves in heavy shafts and wheels is avoided by their use, because the seaters are made to attach to the work when the latter is too heavy to be put on a table. Portable machines are so valuable for tooling exceptionally heavy and massive castings and forgings that they must become multiplied and their growth favoured by the fact that the electrical conductor meets perfectly the old difficulty of transmission of power by cords, belts, flexible shafts, or by steam pipe.

ANOTHER BOX TOOL HAVING A CUTTING TOOL IN FRONT FOR TURNING, AND ONE AT THE BACK FOR "ENDING" PINS AND STUDS

A HERBERT BOX TOOL FOR TURRET LATHE USE, COMBINING A DRILL AND TWO TURNING TOOLS OPERATING SIMULTANEOUSLY

Increased handiness is a characteristic feature of many modern machine tools, and for this, too, the demand will become more imperative. We see it now chiefly in the regulation of speeds and feeds. A matter which still stands in need of much extension is the means of variation in speeds of cutting to suit



A VERTICAL BORING AND MILLING MACHINE BUILT BY W. ASQUITH, HALIFAX, ENGLAND

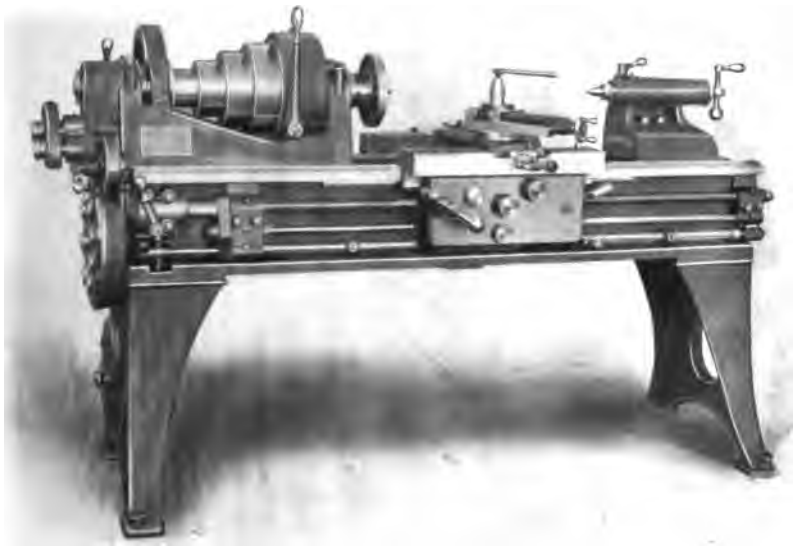
different diameters of work or of tools, and a wide range of feeds easily obtained. When turning, or facing, or cutting circular work it is not desirable to stop the action of the cutting tool or tools. When turning collars and shoulders there is often a difference of 100 per cent. and more in diameters, yet no difference is usually made in the rate of revolution. Neither does it seem worth while in many cases to stop and shift belts. The result is that a good deal of work is turned at a slow rate, which with a better arrangement would be done at a standard rate, uniform with that of other parts. Cutting-off machines are constructed in which a perfect provision of this kind is made, but their utility is limited to a special department of shop practice. The vast majority of lathes and similar machines have no provision of the kind.

But we can anticipate in what way this desirable result will become practically achieved. Although the belt-drive on stepped cones is not an ideal one, yet it becomes nearly so when supplemented by a suitable nest of gears operated by a lever through which from two to half a dozen spindle speeds can be obtained for each step of the cone. No lathe designed for rapid turret and

chasing work is now considered complete without this device, while a good number of ordinary lathes have a supplementary back gear by which two changes for each position of the belt are afforded, supplemented by another at the countershaft. Changes of this kind are made without the necessity of stopping the lathe, so that there is no excuse for running at speeds unsuitable for varying diameters, as there is when a belt has to be shifted.

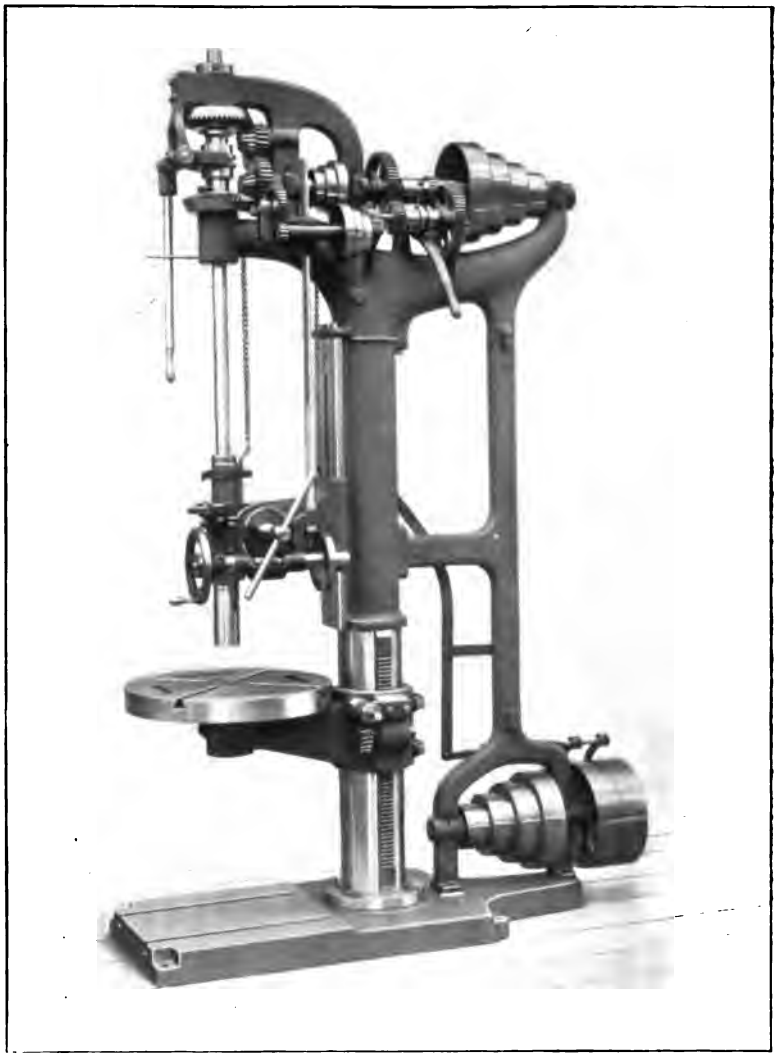
Of a kindred character is the nest of gears by which screws of different pitches are cut on the simple motion of a lever. It is hardly surprising to find how this has come into favour, knowing the loss of time involved in the calculating and setting up of the common change wheels on the quadrant plate. Many lathes are now permanently fitted thus, including several of rather heavy type, in which the time occupied in changing gears bears a less ratio to the time actually occupied in screw cutting than it does in the small lathes where changes are more frequent.

A greater range of feeds than was formerly embodied is now obtainable in several classes of modern machines. As an extreme illustration in some American lathes feeds run up through many graduations as fine as 400 per inch. At the opposite extreme there are the broad finishing feeds of 1¼ and 1½ inches wide of some planing machines. The feeds of many milling machines are now made independent of the spindle speeds, or two or more feeds, twelve in a recent example, are possible through gears for one belt feed. And a most important point in all these is that the variation in large range is effected by the simple movement of a lever without stopping the machines. Ere long there will be no sale for milling machines in which the feeds require the changing of belts on stepped cones.



A LATHE BUILT BY THE SPRINGFIELD MACHINE TOOL CO., SPRINGFIELD, OHIO, U. S A.

Probably at last the problem of producing a wide range of variation in the speeds and feeds of lathes and other tools, with readiness of reversal, will be solved by the electric motor. This has been done by putting reversible variable speed motors in place of the cones. But, however effected, the successful machine tools of the future will undoubtedly possess wider ranges both of speeds and feeds, readily changed without the necessity for stopping or chang-



A DRILLING MACHINE WITH GEARED TAPPING ATTACHMENT. MADE BY THE CINCINNATI MACHINE TOOL COMPANY, CINCINNATI, OHIO, U. S. A.

ing belts for each variation, and also without requiring that the attendant shall leave his position adjacent to the work and the cutting tools.

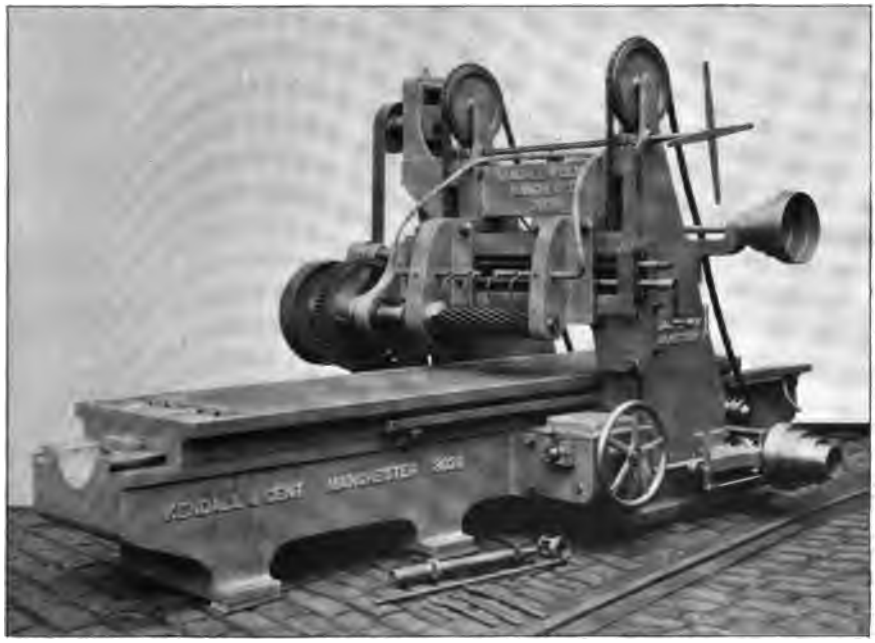
In connection with this it may be observed that when a really good device is invented it is usually found capable of much extension beyond the particular application for which it was first designed. A familiar example of this kind is that of changing speeds and feeds without shifting belts, effected by two or three pairs of gear wheels arranged in reverse positions. Long ago it was put on vertical lathes. Its application to common lathes was rather novel at one time. It is now a frequent fitting on these. It has also been applied extensively to chasing capstan lathes, and has latterly been put, as just mentioned, on milling machines for actuating their feeds. Other illustrations of the same facts will occur to the mind of the reader.

As an example of general unhandiness we must include the time which is lost in the return strokes of the reciprocating machines, and which amounts, with but a few notable exceptions, to from one-half to one-third of the working time. If we add to this the loss incurred in setting the work and tools, we shall see that the actual tooling done on these machines will often not exceed three to four hours per day, and one tool only is more frequently cutting than a couple or more.

But it is easier to point out the evil than to suggest a remedy. There is a limit to the quick return of reciprocating tools, which seems to be fixed in general practice at about two-thirds the cutting speed, though this is more than

One is in the possibility of the use of the Whitworth or other system of reversing tool boxes becoming general; the other in the multiplication of cutting tools, or in the use of tools and machines of greater power.

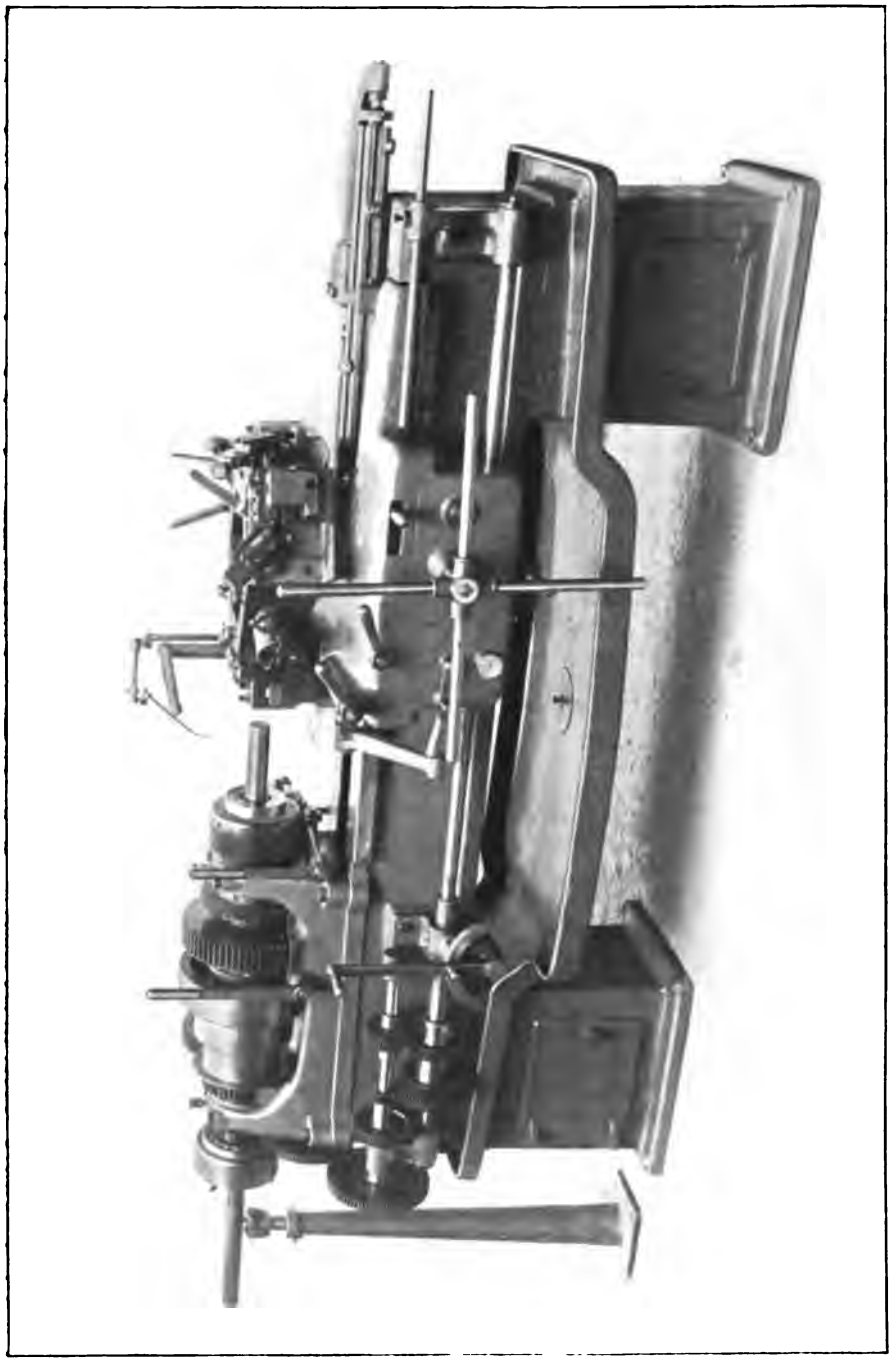
In reference to the first, it must be remembered that reversing tool boxes have been in use to a limited extent for about half a century, and the general disinclination to extend their employment, as well as that of reversible tools, in the slotter points to the conclusion that reversing a tool is not conducive to the best work. Though suitable for roughing cuts, it is hardly so for fine finishing. It is difficult to see how much more can be done in reference to the second matter than has been done



A PLANER TYPE MACHINE WITH HORIZONTAL SPINDLE. BUILT BY MESSRS. KENDALL & GENT, MANCHESTER, ENGLAND

doubled in some instances, using the worm drive. The too rapid momentum of a quicker return would, apart from this drive, be objectionable. It appears, therefore, that there are but two directions in which much further economy may be hoped for in the future.

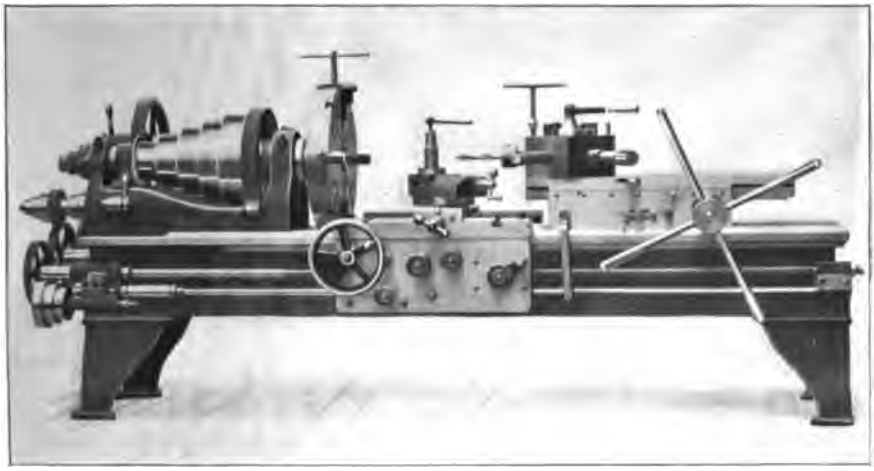
by Sellers, of Philadelphia, and Sharp, Stewart & Co., Ltd., of Glasgow, but the problem may yet be dealt with under the pressure of increasing competition. Unless something is effected in the way of lessening the waste on reciprocating machines, using single pointed tools



HEXAGONAL TURRET LATHE FOR BAR WORK UP TO TWO INCHES DIAMETER AND 24 INCHES LENGTH. MADE BY MESSRS. JAMES ARCHDALE & CO., BIRMINGHAM, ENGLAND

only, the inevitable result will be that an increasing volume of work will be taken from these and put on the milling machine.

Though the milling machine has been greatly improved since its introduction, its latent capabilities are not yet gen erally and fully realised. Whether as a tool for removing material in quantity or for finishing work, there is much room for advance. The practice of staggering teeth, both in the solid tooth mills and in inserted tooth mills, is capable of much extension. If the method of casting mill teeth into the holder is extended, and there seems no reason why it should not be for heavy and occasionally more. Two are employed in lathes having duplex rests, which are used only in special cases; often two in the planer, sometimes three or four; one in the shaper; one generally in the slotter, occasionally two; one in the common drill; one tooth space at a time in ordinary gear cutting machines; and one cutter in a milling machine, though it may be built up of several smaller cutters. To use a larger number than those named above at one time, special machines excepted, is perhaps not within the range of general practice. But there is no difficulty in arranging for consecutive operations without the clumsy and wasteful method



AN AUTOMATIC POWER FEED TURRET LATHE MADE BY THE BRADFORD MACHINE TOOL CO., CINCINNATI, OHIO, U. S. A.

cutters, then it will be possible to make a mill for an odd job or two nearly as cheaply as a smith's die. There is also in every engineer's shop a good deal of irregularly shaped work that is tooled to a line laboriously with single-edged reciprocating tools, with frequent resettings of the work, which, under a ready system of profile tool formation, might be done at a low cost and with greater accuracy. The steady growth of milling machine practice will have to be counted on in the future.

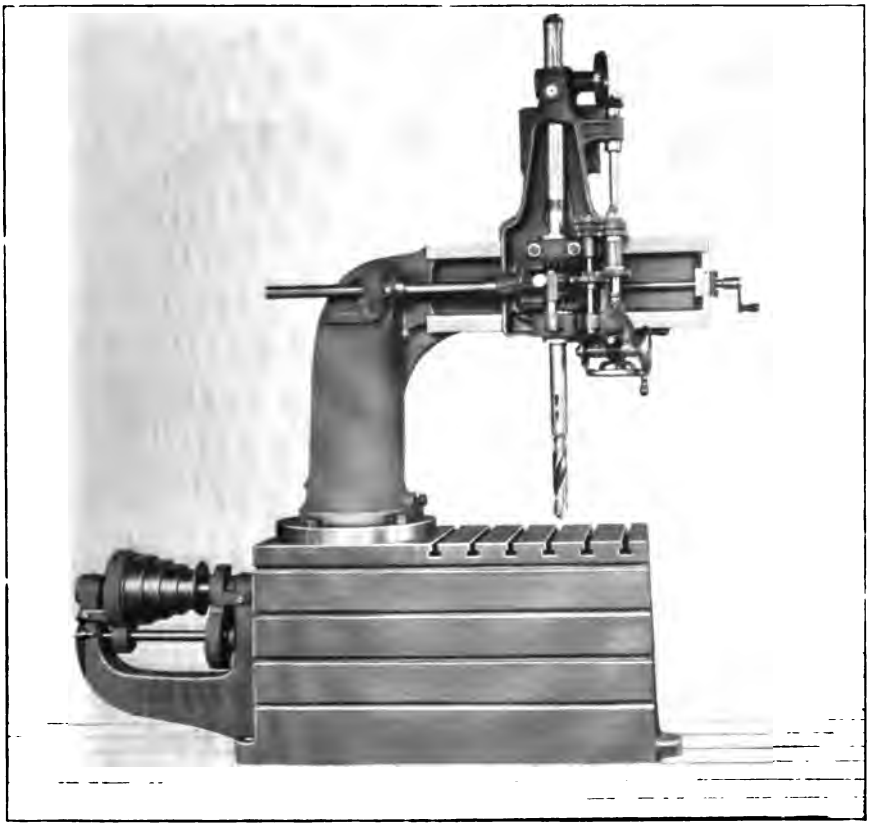
In ordinary practice only one cutting tool is brought into action at once in a single machine; sometimes two are used, of stopping the machine and changing and adjusting tools. It can be done by a simple extension of the capstan tool holder in some cases, and it would be very serviceable in much work of an ordinary kind outside the range of repetitive work, and outside the lathes and drills. Moreover, increasing specialisation in manufacture favours an increase in the number of tools in simultaneous operation, examples of which are furnished by many machines of various types.

The work of the cutting tools themselves might be much increased by better methods of lubrication. The drip

A VERTICAL MILLING MACHINE WITH A 50-INCH CIRCULAR TABLE. MADE BY MESSRS. CUNLIFFE & CROOM, LTD., MANCHESTER, ENGLAND

can still survives,—a very inefficient device in heavy cutting. To perform heavy duty without undue heating, a tool must be flooded with the lubricating agent. Not only is it necessary to maintain a constant stream, but it must be forced to the tool point under pressure. How much may be done in this direction is seen in modern automatic screw machines and others of a kindred type for pins and hubs, and in milling machines. Without ample lubrication, effected under pressure, these machines would not be half so efficient as they are. What has been done for these might well be done in lesser or equal degree for all machine tools. The latter, it is true, have the disadvantage that the work done upon them involves a wider variation in the positions of the tools and of the work than is the case on the special tools just mentioned. But that is a matter of detail which can be easily worked out by systems of jointed pipes.

As a last example of handiness, take the employment of the useful cabinet leg under the headstock, now so common a device, which may have had its birth in the large leg that is brought down beneath the gap in the common lathe of heavy type! In the screw machines, gear cutters, the surfacing and other lathes, milling machines, grinders, and kindred forms the bed is usually prolonged to form a cabinet leg of the same, or nearly the same, length as the bed of the machine. Gear cutting machines have their racks for change wheels, and planing machines their bolt racks, and most tools have racks for their spanners. Others have their tool

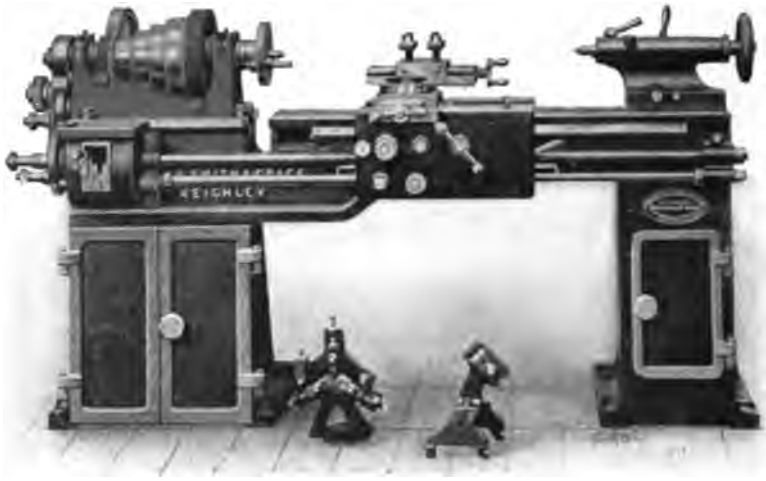


A RADIAL DRILLING AND TAPPING MACHINE MADE BY MESSRS. SMITH & COVENTRY, LTD., MANCHESTER, ENGLAND

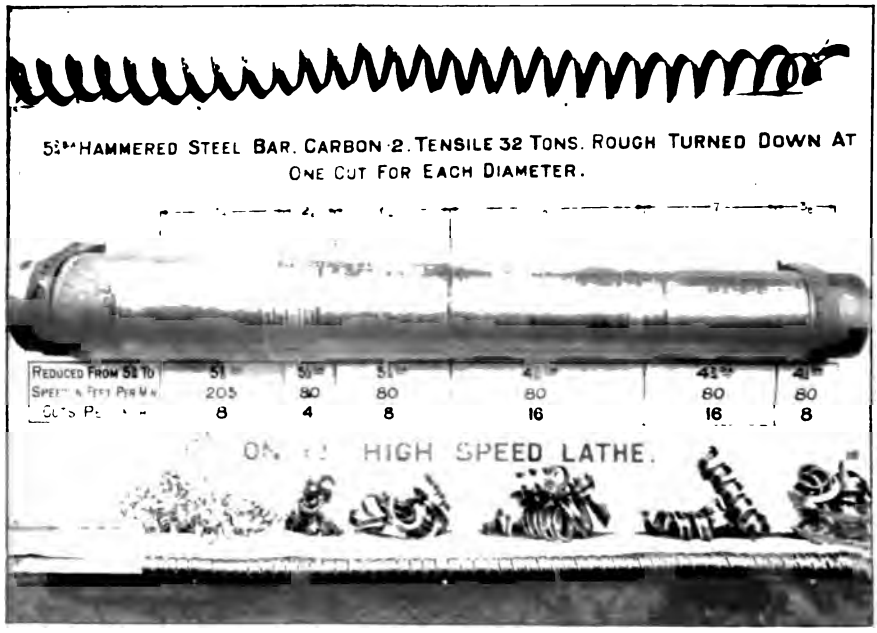
trays. These are not trifles, but valuable secondary characteristics in that evolution in the direction of order by which the modern machine shop differs from its predecessors. It is a real delight to look at any modern high-class tool and note the myriad of little provisions for multiplying its utilities and preserving its efficiencies. There are neat adjustments, bushings, protecting coverings, trays, oil holes, flowing outlines, rounding edges, cleanliness and order, all well provided for.

The growth of, and increasing demand for, excellence of workmanship must, of course, be taken with exceptions. Much of the hand fitting of years ago was as good as the best that is turned out now. But the difference is this, that precise machine work, as milling and grinding, occupies a more important position now that the best machines and engineers' work are made to precise gauged dimensions, while in the old ones mutual fitting of parts instead of precise dimensions was the practice, which rendered interchangeability impossible. And apart from this it must be conceded that the general level of practice has been raised. Formerly a few machines,—the specialities of a few firms,—were excellently made; now large numbers of machines, turned out from many shops, leave little or nothing to be desired. This follows in a large degree from the introduction of so many modern machines of precision and of gauges into the manufacturing shops.

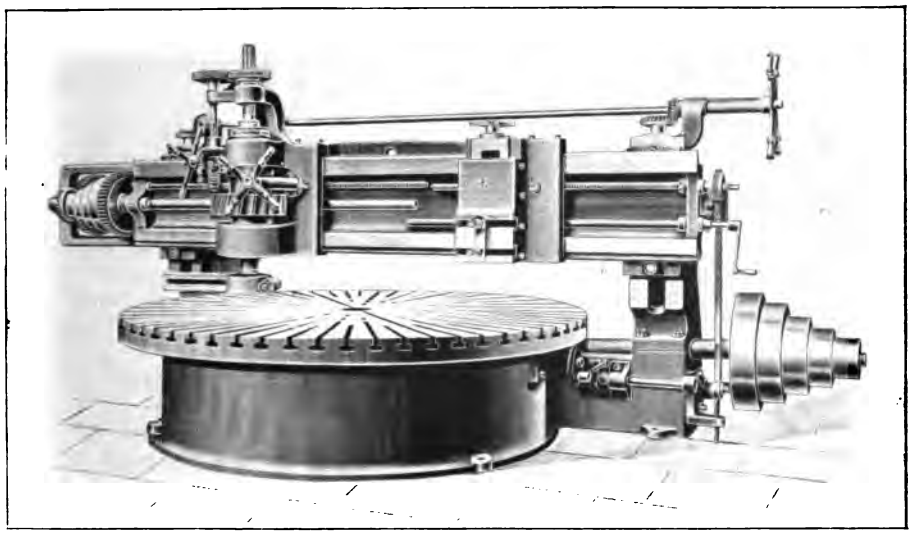
On all these lines we may anticipate that the future of machine development will continue until every class of tool



A 12-INCH HIGH-SPEED LATHE MADE BY MESSRS. DEAN, SMITH & GRACE, LTD., KEIGHLEY, ENGLAND


5¼" HAMMERED STEEL BAR. CARBON .2. TENSILE 32 TONS. ROUGH TURNED DOWN AT ONE CUT FOR EACH DIAMETER.
REDUCED FROM 5¼ TO
SPEED IN FEET PER MIN.
CUTS PER MIN.
5¼" 205 8
5" 80 4
5" 80 8
4¾" 80 16
4½" 80 16
4" 80 8
HIGH SPEED LATHE.

THIS ILLUSTRATION TELLS ITS OWN STORY. THE WORK WAS DONE ON ONE OF THE HIGH SPEED LATHES SHOWN IN THE UPPER ENGRAVING



A MACHINE FOR TURNING BOILERS ENDS, UP TO 9 FEET IN DIAMETER, AND FOR CUTTING OUT FLUE HOLES. MADE BY MESSRS FRANCIS BERRY & SONS, SOWERBY BRIDGE, ENGLAND

will embody some one or more of these features. We shall see more powerful machines yet, capable of heavier work than their present representatives are; capacities will grow, and larger numbers of portable machines will be used. Into the lighter machines chiefly handy arrangements and more of automatic and semi-automatic motions will be introduced, until "one man, one machine" will be but a lost legend, while the higher standard of excellence of workmanship now embodied in certain tools will be extended to include all others.

The present trend is unmistakably in the direction of throwing a large volume of work on the automatics. From their earlier forms of simple screw machines they have grown until now they embrace an ever-increasing stream of articles of all conceivable shapes and larger and larger bulk, the dimensions of which are limited only by the bore of the hollow spindle to which the term "bar feed" is now more applicable than "wire feed." And beyond this castings can now be chucked automatically in the machines, in which case the bore of spindle has nothing to do with the size of work chucked. The number of operations that can be performed in one cycle increases still,—performed in turrets that carry sets of box tools, and in cross slides holding broad forming, or knurling, and cutting-off tools. The long rows of automatics in some of the modern shops are a revelation to many engineers, testifying to the extreme value of specialisation in modern engineering.

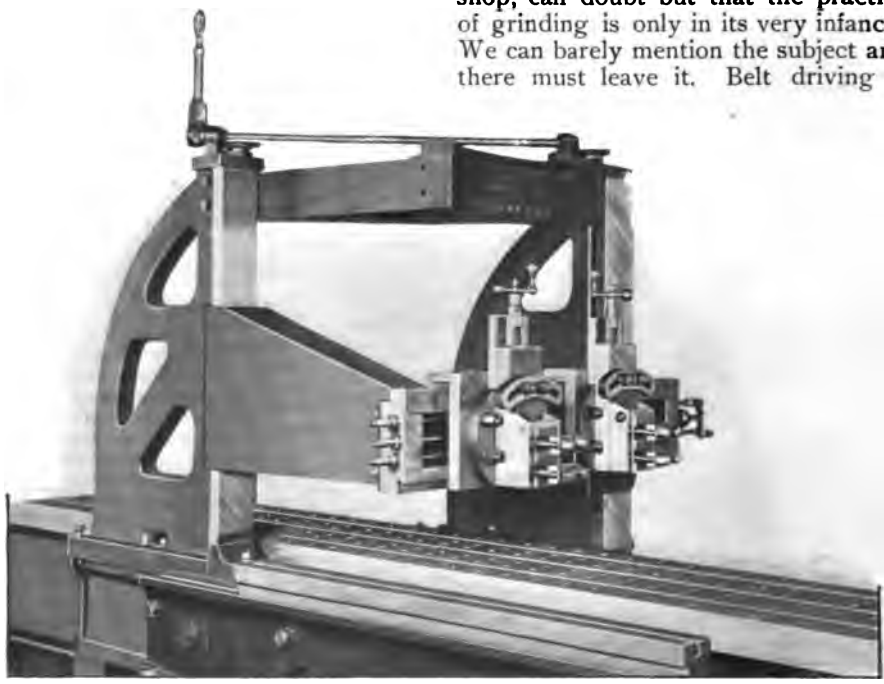
Yet we are justified in hazarding the statement that the automatic screw machines are still in an early stage of their development. One existing design,—a four spindle automatic machine,—marks an important advance, since in this machine four operations, or sets of operations, are proceeding simultaneously on four distinct bars gripped in four separate spindles. The capacity of a single-spindle turret screw machine is, therefore, multiplied fourfold, besides which there are other advantages, such as the simplification of cams,—one cam serving for operating the one tool head that carries the four tool spindles. The economy, too, is so great that in the shop where this machine is made fifty machines are run by seven men, and as each has four spindles, it means that each man is looking after about twenty-

eight spindles, the equivalent of twenty-eight turret lathes.

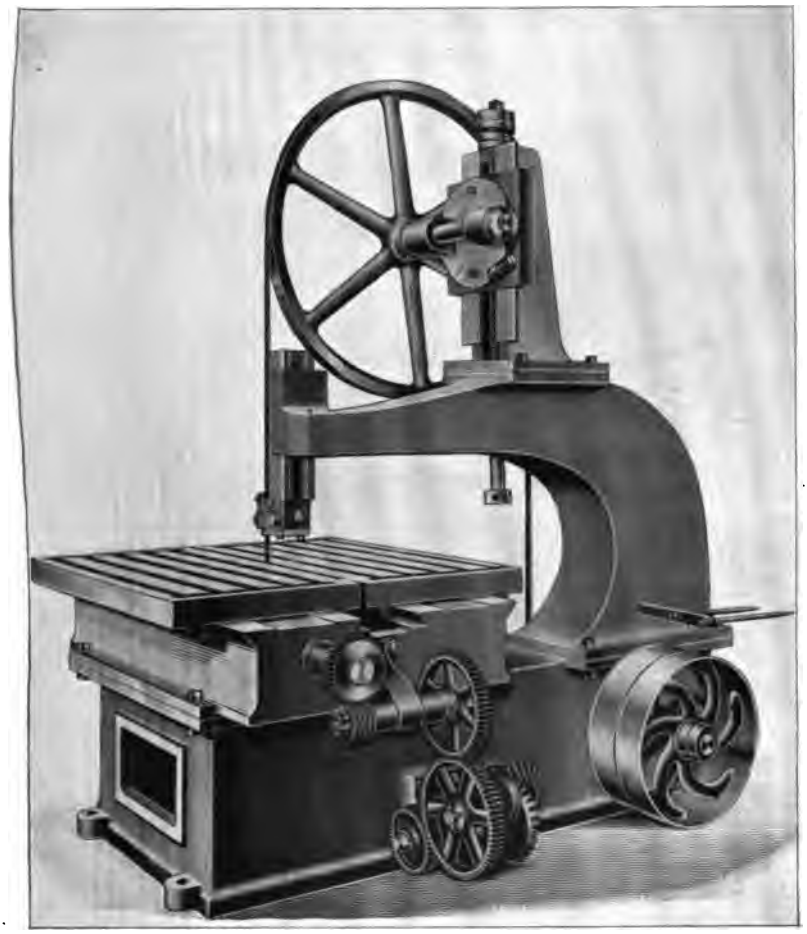
Closely related to the automatics is the large class of semi-automatic machines, tools which are destined to a yet larger growth. They differ from the automatics in being destitute of the cam shaft method of operation; they resemble them, and differ also from the common lathe, in possessing turrets, cross slides, hollow spindles with wire feeds, and automatic chucks, and in the frequent addition of chasing saddles. They approximate more to the automatic machines than they do to the ordinary lathes, though possessing features common to both. Any number of similar pieces can be tooled upon them to precise dimensions without any checking by rule or calipers or other gauges, dimensions being fixed and the movements of the tool arrested by stops. Their capacity constantly increases, so that they now embrace forgings and castings, besides bar work. If a casting or forging requires, say, from a dozen to twenty distinct operations, they can be done in the most modern semi-automatic lathes in a single cycle. Rarely is a dozen operations exceeded, while many pieces require only three or four.

Economy in time is studied more than heretofore in machine tools. The use of stops,—a separate stop to each tool in the most perfect machines,—permits the work to go on unceasingly without arresting it for measurement. Turrets are also speeded to rotate more rapidly between the operations of consecutive tools; turret slides are brought back sharply, and different rates for turning and threading are provided.

An immense development in grinding is already in rapid progress, the later growths of which may be of a startling character. In most British shops the grinding department bears but a small proportion to the others. Yet who that is aware of the capacities of the later machines, their exquisite precision, their economies, the scores of designs in which they are offered to meet all possible requirements of the machine shop, can doubt but that the practice of grinding is only in its very infancy. We can barely mention the subject and there must leave it. Belt driving is



AN OPEN-SIDE PLANER MADE BY THE MARK PLATHER PLANER CO., NASHUA, N. H., U. S. A.



A BAND SAWING MACHINE FOR CUTTING IRON AND STEEL COLD, BUILT BY MESSRS, NOBLE & LUND, LTD., FELLING, NEAR NEWCASTLE-ON-TYNE, ENGLAND

a wasteful and inconvenient method of driving. The tendency is towards its abolition, or its partial use only. Belts absorb much power; they often interfere with the hoisting of work, they obstruct the light, are dangerous, and wasteful of time in shifting from step to step. In a few cases the belts are arranged underneath the floor, leaving the workshop clear. But this is rarely done, and is objectionable from some points of view. The only way in which belt driving will be got rid of, or at least reduced to reasonable limits, appears to be in the spread of electric driving. We may expect that electricity will in a few years displace most of the main belt drives, first by the group system, and then the latter system of driving which retains the machine belting will disappear in favour of an all-electric drive, that is, a separate motor on each machine.

The possibility of some of these changes may appear chimerical to the old-time turner or machinist who deems the machines to which he has become accustomed practically perfect. But in the severe pressure of competition which will try the nations during the next quarter of a century much will be accomplished in the directions here indi-

A SHAPING MACHINE MADE BY THE CINCINNATI SHAPER CO., CINCINNATI, OHIO, U. S. A.

cated of which the present generation scarcely dreams. Only under pressure will developments such as those suggested take place.

As far as one may venture to forecast the future, it does not appear probable that the practice of the tooling of metal will be revolutionised by any radically new methods. It is hardly likely that there will be any such sweeping changes in practice as those which followed on the invention and application of the slide-rest principle, or of the planing machine, or of milling. On the contrary, though new machines are being constantly introduced, they are all, in greater or less degree, modifications of those which were in existence half a century or more ago.

But the most notable feature of modern machine tool development is the increased attention which is devoted to what are deemed minor details,—trifling economies relating to time, with or without improvement in the product. This follows as a natural result from the fact that the number of firms who are devoted to the manufacture of a limited number of special tools is on the increase. The best tools come from these firms. There is no such thing as a repetition of old, unchanged designs, but every year brings some modifications, often apparently trifling, the sum total of which, in time, puts a machine far ahead of its prototypes and of its standard congeners.

The result of a very high degree of specialisation will probably be of a startling, and, to many, unexpected character,—the survival of the fittest, a single machine, or two or three kindred types of machines, monopolising the market. The trend appears to be inevitable, and the firms who early recognise it will be wiser in their generation than those who ignore it.

THE QUALITY OF PRODUCT IN PIECE-WORK

By Sanford E. Thompson

VARIOUS systems of piece-work have been evolved in manufacturing establishments in recent years for the purpose of increasing the volume of output. In formulating these systems the chief object on the part of the employer has been to place before his workmen an incentive to produce a larger number of pieces per day with the least possible increase in the total daily wages earned. The method of maintaining the quality of the product after the introduction of a piece-work system is a subject which has been touched upon only slightly, though it is a matter of as great importance to most manufacturers as the actual cost of getting out product. If the work done be simply of a muscular nature, such as shoveling coal or unloading pig-iron, the matter of quality of the work does not enter into the question. In other slightly higher classes of work, where the structure of the material is not altered by the workmen, it is often a simple question whether the work has been done right or wrong, and if wrong, then it must be done over again. By far the larger number of piece-work operations, however, are dependent for their proper performance upon the skill, as well as the speed of the operator. If a piece is carelessly made, not only is the time of the workman wasted, but the material also, or in some cases the tool used by him. Every manufacturer, therefore, who is considering the introduction of piece-work into his establishment must decide how such an introduction will affect the quality of the goods which he has to market. It is a very common saying among the advocates of paying men by the day that while piece-work will increase the volume of product, day-work must be resorted to wherever extra quality is required. This is undoubtedly true if no more precautions be taken under the piece-work system to produce good work than under the day-work system, for the average man on piece-work will slight his work if he be allowed to do so. But piece-work where properly handled can turn out goods of better quality than can be secured by day-work. This is a strong statement, but it is not simply the opinion of the writer alone; it has been proved in shops where the very highest quality of workmanship is required.

The secret of maintaining or improving the quality of a product after the introduction of piece-work lies in the methods adopted for inspection of the work and in the penalty to the workman for imperfect work. Another requisite for success is that the men on piece-work must, if they do more work, earn a larger sum per day than their former day wage. A man who is working at a high rate of speed must have a proper incentive not only to maintain this rate, but also to do his work with care.

It is impossible to give rules which will exactly apply to all establishments, but there are certain fundamental principles which may be stated, and in illustration of these a test will first be described which was made by the writer to determine the relative quality of certain articles worked upon by the day and produced at a later date entirely on the piece-work plan.

This test to determine the relative efficiency of day-work and piece-work was made upon a product offering great opportunity on the part of the workers to shirk if it had not been for the employment of very careful inspection and

carefully arranged penalties. The piece-work was in itself inspection work, and illustrates the extent to which piece-work may be employed. The foreman of the department where this was carried on and the superintendent of the factory declared that it was impossible to use piece-work methods and maintain the quality; but the result of the test showed that the quality was not merely maintained, but improved.

One branch of the factory was devoted to the manufacture of bicycle balls, and the department here specially referred to was the inspecting and shipping department of the plant. Bicycle balls range in size from 1/8 inch to 3/8 inch in diameter, while for other purposes similar steel balls are made up to 2 inches in diameter and even larger. The balls are all made from steel rods of the proper diameter, and after being finished on the machines and polished, are sent to the inspection department for the removal of defective specimens. They are then boxed and shipped as required. At the time that piece-work was introduced by the writer in this department about fifty girls were there employed. Piece-work was introduced not only in the inspecting but also in the gauging, which consists in the separating of the balls so that those in any one box will not vary from one another by more than, say, 0.0003 or 0.0004 inch, and in the boxing.

The day's work of each man in the shop in grinding the balls is kept separate, and his pay is affected by the number of poor balls in his lot. All of the balls receive in the inspection room a double inspection, that is, they pass through the hands of two sets of girls, and in addition, small portions of each girl's work are tested by one girl who acts as "over-inspector." The over-inspector is paid by the day; all the others are paid according to the quantity of balls which they look over. The object of the inspection is to remove all balls which are defective. The defects which are visible are fire-cracks, soft spots, and rough or flat places. Some of these are due to variations in the quality of the steel, and some to defective machine work. To the untrained eye the balls, as they come from the shop, appear uniformly perfect, and the skill necessary for detecting the slight flaws is attained by the girls only after months of practice. This may seem like an unnecessarily full description of the methods of manufacturing, but it is given to show the fine quality of work required, and the great opportunity for slighting the work possessed by girls, who inspect in some cases hundreds of thousands of balls per day, without a very careful system of reward and penalty.

The regular work in the inspecting department consists essentially of the following operations. A girl from those who make the first inspection is given a lot of balls and removes all the poor ones which she can find. The good balls of this lot are then given to a girl who performs the second inspection. She looks over them in a slightly different way, picking out all of the poor ones which were left in by the first inspector. The piece-rate per thousand balls inspected by the first inspector is based upon the number of poor balls which she overlooked and which were found by the second inspector. Small samples from each lot are then given to the over-inspector, and the rate of pay per thousand balls of the second inspector is based upon the number of poor balls found by the over-inspector.

The work of the over-inspector is occasionally checked up by the foreman to see that she is doing her work faithfully, although a girl for the office of over-inspection is selected only after she has proved herself to be absolutely honest and trustworthy. The total number of poorly machined balls found by these girls in the lot of any one man in the shop determines the rate of pay per thousand which this man shall have for grinding or whatever work he does upon the balls.

Let us turn now to the test of the quality of work in the inspection department described after the introduction of piece-work, in comparison with the quality produced by the same girls before its introduction. In the store-room of the department were stacked boxes

of balls, marked in such a way that those inspected on day-work were readily distinguished from those inspected on piece-work. Six samples of 500 balls each were selected at random from a number of boxes which had been put up previous to the introduction of piece-work. Similar samples of the same sized ball were taken at random from balls which had been inspected and boxed after piece-work was applied. Each lot was marked by the writer with a private mark and given to one of the best inspectors in the room. Theoretically, of course, there should have been no defective balls in any of the lots. As a matter of fact, however, extremely minute defects which are scarcely observable without the use of a microscope and which do not affect the structure of the ball, will not injure it in the slightest degree for use. The degree of care in inspection, therefore, depends upon the number of defective balls and the size of the defects which have been allowed to remain in the balls for boxing. In the test described the balls were inspected very carefully for poor specimens, the most minute defects causing their removal.

The result of the test showed that in the boxes inspected by day-work there were about 50 per cent. more of these minutely defective balls than in the boxes inspected on piece-work. The sizes of the defects in each case were about the same, and in both cases they were very small. Taking into account the total number of poor specimens usually found in balls, the piece-work inspection showed at least 10 per cent. better work than the day-work inspection. The girls, it should be noted, were not only doing about 10 per cent. better work under this piece-work system, but they were turning out about twice as much product per worker as they were when working by the day, and they were doing this in a shorter day than before.

Basing conclusions upon this example and upon other piece-work results in manufacturing establishments, a few general laws may be stated which may be of use to employers of men at work by the piece. The simplest class of piece-work, which consists of muscular work, such as shoveling coal or handling pig-iron, requires, as has been already stated, no inspection.

A second class of piece-work may be considered to consist of operations which require a slight degree of skill on the part of the worker, but which, if performed in a wrong manner, can be done over without affecting the materials used. In such work the penalty for poor performance need be merely the correcting of the error made, with full payment for the actual completed work.

A third class of piece-work involves work, the poor performance of which, besides taking the time of the worker, injures the material used or the tool employed to do the work, or necessitates the loss to the employer of previous labour performed upon an article, or is in other ways detrimental to the interests of the employer.

This third class, and, in fact, each of the other classes as well, may be separated into work done in gangs where a number of men divide the payment, and work done individually where each man receives the reward of his own labour alone. The former, especially in Great Britain, is often designated contract work, in which case it involves a special agreement between the employer and the employed. With the gang and the individual the general principles to be followed in inspecting the product are similar.

Individual piece-work where properly handled, gives the worker the greatest incentive to exert himself. Sometimes the decision as to whether the work shall be done individually or in gangs depends upon the method of inspection adopted; that is, whether the work of each man shall be kept separate, or whether the products of all shall be put together. It is almost always safe to assume that where such separation can be made, the extra labour required in clerical work and handling will be more than balanced by the increased amount and quality of work which the man will turn out. Piece-work by gangs, however, can be satisfactorily arranged and

the work can be properly inspected where the other method is not feasible.

Inspectors must always be of the highest character and ability. This is especially necessary where the work is of such a skilled nature that the inspector must be an expert at his trade, because then there is the greatest opportunity for favouritism. Work should come to the inspector marked in some way so that he will not know the names of the workmen. This not only prevents the possibility of favouritism, but also makes it easier for the inspector to show up every defect.

Even a first-class inspector is liable, at times, to get careless, and sometimes the foreman or employer may use poor judgment in selecting him, or he may be bribed by the workmen to send in good reports. It is advisable, therefore, when possible, to have two independent inspections of the same work. If perfection is not absolutely required in every piece it is often sufficient to have one inspector or set of inspectors who go over all of the work carefully, and then have one man whose character is above reproach to select samples from the work of the under-inspectors and see if the average results from these samples correspond with the total results obtained in the first inspection.

The method of fixing the penalty for poor work upon the workman is of fully as great importance as the method of inspecting. Some penalty for poor work is absolutely necessary in any properly conducted piece-working establishment; otherwise the only guards against defective product are the integrity of the workman and his fear of discharge. Neither of these can be counted on to have the desired effect day in and day out. If, on the other hand, a man's pocket-book is affected, if he knows that poor work will give him less pay even if the quantity is large, he can be depended upon to turn out perfect product with scarcely any watching.

There are four general methods which may be applied in fixing penalty, their selection depending upon the character of the work, the time which it requires for a workman to produce a single piece, and upon the loss which will be occasioned by a poor piece. Some of these are based upon principles of the Taylor differential piece-rate system treated of in this magazine for October, 1895. The methods are as follows:—

1.—By requiring the workman to repeat the operation in his own time. This can be done only where the material itself is unaffected by the workman's error.

2.—By allowing the workman no pay for the poor work which he performs. This method may be used where the defective product is a complete loss to the company, and where the simple loss of time on the poor work is of sufficient detriment to the workman to make it an object to him to do perfect work all of the time.

3.—By giving the workman no pay for his poor work, and, in addition, basing the piece-rate on all the perfect work upon the number of poor pieces turned out. For example, suppose that the regular rate per piece for performing an operation is 5 cents. If, in the course of a day, one piece is spoiled, the rate per piece for all of those properly performed may be 4.9 cents. If two pieces are spoiled in the course of a day, the rate per piece for the good work may be 4.8 cents, that is, there will be a deduction of 0.1 cent per piece for each defective piece. The equity of this arrangement is based upon the fact that the poor pieces cause a loss not only of the time of the man, but the time of the machine he works upon, the labour already spent by previous men upon the poor piece, and the materials composing it. This method should not be resorted to, however, unless the poor work is due entirely to the workman's fault and could have been avoided. It should not be adopted either if the result would be to occasionally bring the wages of a good man much below the average rate.

4.—By adjusting the rate upon all of the work which a man does in a day by the degree of perfection of his entire day's work. This method is similar to that last described, except that the man receives pay for all of the work which

he does. It is especially preferable where defective work does not make it entirely unfit for sale, or where the resulting product can never be absolutely perfect, though the aim is to have it as good as possible. An example of this method of fixing penalty is given above in the description of the fixing of rates in the inspection department.

It is always necessary to arrange rates and penalties so that a man who does an extra day's work in quantity and quality will receive higher than average wages, and receive these permanently, without fear of a cut.

The cost of inspection work has not been touched upon. While this is important and while methods of inspection should be systematised as much as possible, the perfect performance of work is of greater importance. When properly conducted, so that the men have permanent incentives to do fast work, the cost of inspection will always be tremendously overbalanced by the extra product turned out by the workmen. Besides this, less superintendence is required, because the foremen can trust the men to turn out the best work they know how; if they do not, they will feel it in their pay envelopes at the end of the week or the end of the month.

MACHINE SHOP FLOORS

By Milton P. Higgins

THE modern practice of building machine shops of one-story construction has developed some very important considerations, and not the least of these is the character of the floor and its support. One of the chief advantages in ground floor machine shops is to be secured from the right kind of flooring supported continuously on the ground. As heretofore constructed, such floors may be divided as follows:—

1st.—Solid, non-elastic, heat-conducting floors of stone, brick, cement, or cement-concrete.

2nd.—Semi elastic, semi-heat-conducting floors of earth, macadam, tar-concrete, or asphalt.

3rd.—Elastic, non-heat-conducting floors of wood or those of which the wearing surface is wood.

Floors of the class first mentioned above have been used to a considerable extent in Great Britain and on the Continent, where it has been customary in buildings of all kinds to make the ground floor of stone, marble, cement or brick, wherever possible, in preference to wood. They are not now, however, being so generally laid in machine shops and factories. The chief objection common to floors of this class and of the second class above, is that of cold and dampness, which are not only uncomfortable, but oftentimes dangerous to the workmen. In many Continental shops the custom among workmen of wearing wooden shoes or heavy hob-nail boots, keeping the feet removed from the stone-like surface of the floor, overcame this objection to some extent. In some cases, too, where this flooring has been adopted the men have been known to provide themselves with boards or small wooden platforms in front of their machines. The man with cold feet is not apt to be an efficient workman. "Keep the feet warm and the head cool," is a good rule to follow in the shop.

The brick, stone, and cement floors are furthermore non-elastic, fatiguing to walk and stand upon, subject to wear by wheels of heavy trucks and repeated dropping of heavy castings and other things, and the injury is not confined merely to the floor itself, but frequently the goods unloaded or deposited suffer more or less, unless constant care be taken to prevent it. Furthermore, there appears to be no kind of cement or concrete which is not objectionable on account of gritty dust. These floors are not easy to take up or to repair, and have little to recommend them as desirable machine shop floors.

Floors of the second class, consisting of earth, cinder, macadam, tar, and asphalt, are hardly more satisfactory. Cold, dampness, and gritty dust are disadvantages not to be tolerated in a machine shop. The earth floor does possess the advantage of cheapness and in some degree the advantage of elasticity. It is well adapted for some places where concrete or cement floors are now put down, as, for example, in forge shops. It is cheaper, easy to lay, break into and repair, and would probably under many conditions where cement floors are used, be as satisfactory as the latter, particularly if laid as first-class macadam should be laid. The earth should be excavated for a depth of from twelve to twenty four inches, depending upon the character of the soil. If necessary, drains should be provided. A layer of coarse broken stone should be packed in solidly and

upon this, layers of stone, increasing in fineness, should be well rammed, the last layer being of clean, coarse sand. Trucking on this floor should be done with broad-tired trucks. The floor should be occasionally sprinkled and rolled, and any worn or broken places should be cut out and thoroughly repaired. The macadam floor, however, is hardly adapted for a machine shop unless covered by a wooden flooring as hereinafter described.

The tar-concrete and asphalt floors have, to a considerable extent, the desirable elastic quality, and a fairly satisfactory non heat-conducting quality, but on account of it being impossible to prevent almost everything left directly on the floor from becoming embedded in the

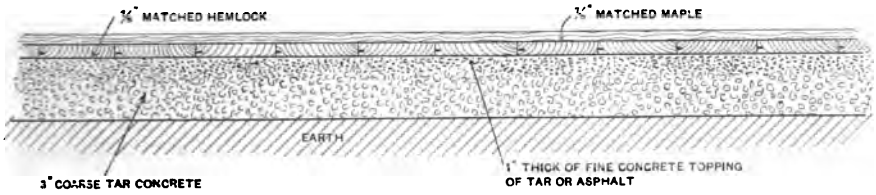


FIG. 1

surface, these floors must be rejected for most places except as foundations for a continuous wooden flooring, for which they have very marked advantages.

Upon the whole, there seems to be nothing so desirable for shop floors as those of the third class, having a wooden wearing surface. They possess the requisite elasticity: They are non heat-conducting to a greater extent than any other available material; they are cheap, easily laid, repaired, and renewed, and, when properly laid to provide against decay, will last a very long time. A good shop ground floor should be considered as a continuous wood carpet, from two to five inches thick, with a continuous support or foundation underneath.

For all kinds of severe use, no wooden surface is so satisfactory for the wearing surface as rock maple, seven-eighths of an inch thick and not over two and one-half or three inches wide, matched on the ends as well as the sides, or not matched, as desired, and bored for blind nailing. It is the usual practice to employ unmatched flooring, the advantages argued for it being that it can be worn through without slivering at the tongues and grooves as would be the case with matched flooring, and that it is easier to take up a board and repair than where this latter flooring is used. It has been the experience of the writer, however, that the slivering of tongued and grooved flooring has been greatly exaggerated, and that where there is any necessity for removing a matched board the tongue can be very easily split off and the repair made with unmatched stock without disadvantage. The advantages of evenness, solidity, and firmness for the matched floor are believed to overbalance any advantage to be claimed for the unmatched stock.

This wearing floor, running lengthwise of the shop, should be well nailed to matched planking, usually from two to four inches thick, running crosswise of the shop. This affords one continuous, homogeneous carpet of wood, from about three to five inches thick, and, when laid on a continuous foundation, makes a floor strong and solid enough to support all goods and machinery except very heavy machine tools requiring a special masonry foundation. Machines heretofore considered too heavy or too jarring in their operation to be placed on the strongest floors of an upper story, can be safely and perfectly supported on such a ground floor without special masonry foundation.

The planking should be of hard pine, spruce, or hemlock. If the foundation of the floor is constructed as it should be to take the heaviest weights, the

planking need not be over two inches thick. With a properly constructed foundation for such a floor, it has been found by experience that even ⅞-inch matched boards are very satisfactory for the under flooring. This is shown in Fig. 1. The lower layer may be of cheap hemlock of any width, but about six-inch preferred, matched and laid running crosswise of the shop. Upon this is laid a ⅞-inch matched maple wearing floor about two and one-half inches wide, running lengthwise of the shop and well nailed to the hemlock boards. Special attention is called to this flooring because of the use of only ⅞-inch boards for the under floor. This makes a cheap floor with 1⅜ inch thickness of wood. This is preferably supported on a continuous foundation of tar-concrete or asphalt as will be hereinafter described. As the office of the under floor is simply to hold the upper maple flooring in place, it seems to answer every purpose of two or three-inch planks, except in case of the heaviest machinery, where the weight might be likely to sag this floor into the tar-concrete.

As the object of the under planking is simply to hold the wearing surface firmly in place, the thickness of this under flooring is largely dependent on the kind of foundation used. With the proper foundation it should be made of a thickness which will resist decay just about as long as the wearing floor will wear. When the under flooring is decayed, the wearing floor should be worn out, if economy is an object.

The rapidity of decay depends on the character of the ground on which the building is located and on the kind of support or foundation for the wooden floor. Until recently it has been the custom, even when plank floors have been supported continuously by cement, earth or concrete, to imbed timbers to which the planking is spiked. As supports, these timbers are quite unnecessary, while as cleats or as means of holding the planking together, they are also needless, because the top or wearing floor is sufficient for this purpose. The practice of using large supporting timbers came from thoughtlessly adhering to the method used in upper floors, and with this went the idea that the air space under the ground floor was desirable. On the contrary, this has been found to be very objectionable. It has been proved to be the cause of rapid decay from dry rot. Dead air space and dampness are found to promote decay to a greater extent, even, than direct contact with water. Moreover, fires have been known to originate beneath such floors.

Besides the consideration of decay and fire, obvious advantages are secured from a continuous support at all points, thus making the floor free from jarring, deflection, and noise, even when subject to heavy blows, moving of heavy weights, and the shaking of vibrating machinery. Special foundations for machines are necessary only in special cases and special preparation of parts of the foundation of the wooden floor may provide for some of these cases.

If such a flooring should simply rest upon the ground with a top of sand well rammed or rolled, the result in most cases would be satisfactory so long as the floor resisted decay. The natural earth support is the cheapest and in some locations free from dampness, with well-drained soil and a top filling of small stone, the floor may last a long time. It has been suggested that if a layer of air-slaked lime, from half an inch to an inch in depth, be placed upon the gravel before laying the floor, it will serve as an additional protection to the wood.

The use of Portland cement as a foundation for the flooring has not met with much success, the decay being very rapid unless the flooring be protected with a coating of coal tar mopped on or resin poured in as described below.

Coal tar concrete or asphalt is probably the best foundation available. The testimony of those who have used it is unanimous as to its preservative powers on wood. Such a floor has been laid by the Pratt & Whitney Co., of Hartford, Conn., and has been described in one of the reports of the Boston Manu-

FIG. 2.—FLOOR CONSTRUCTION IN THE SHOPS OF MESSRS. LUDWIG LOEWE & CO., LTD., BERLIN

facturers' Mutual Fire Insurance Company as follows:—"In laying a basement floor, about eighteen years since, of 10,000 square feet, 8000 feet were laid in coal tar and pitch concrete in about equal proportions, and 2000 feet were laid over cement concrete. The latter portion of the floor was renewed in about ten years, the timbers and the plank being completely rotted out, coal tar and pitch, and finally about one inch of fine gravel concrete. Before the concrete was laid, heavy stakes were driven about three feet apart, to which the floor timbers were nailed and levelled up. The concrete was then filled in upon the floor timbers, and thoroughly tamped underneath up to the level of the top, rounding the concrete between the floor timbers and

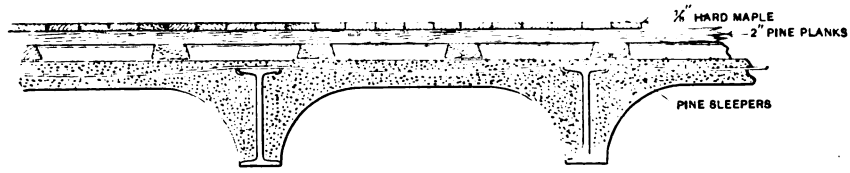


FIG. 3.—DETAILS OF THE FLOORING IN THE SHOPS OF MESSRS. LUDWIG LOEWE & CO., LTD.

while the other was in a perfect state of preservation, and has continued so until the present time. How much longer it will last we cannot tell.

"Excavation was made about one foot below the floor, and six inches of coarse stone were filled in, then five inches of concrete made of coarse gravel, rolling it down. Upon these timbers the floor was laid. The timbers on the under side of the flooring were covered with hot coal tar. It is very essential that the gravel should be perfectly dry before mixing, which is done by putting hot coal tar upon the gravel, and raking it together. In order to get the mix-

ture so that it will be dry, hot pitch should be mixed with it, and boiled so that when cool it will become perfectly hard. What is known as distilled or refined coal tar must be used, as that which comes from the gashouse without being refined does not work in a satisfactory manner."

Substantially like this floor is one laid by the Yale & Towne Manufacturing Company, of Stamford, Conn., of which Figs. 4 and 5 are illustrations.

Another floor referred to in the above report, to be found in the works of William Sellers & Co., of Philadelphia, is shown in Figs. 6 and 7, and is described as follows:—

"The earth is first removed, so that it does not approach either the floor timbers or the plank, and a layer of sand fills the space. Spent moulding sand was used in this case. The timbers are then placed in the trough made by the bricks, which bricks are laid without mortar. Melted resin is poured into the space alongside the timbers, which are also placed so that the resin will flow underneath, protecting the under side. The floor planks were then laid upon the timbers about half an inch above the level of the sand. Melted resin is then poured through holes bored in the floor plank about four feet apart, so as to interpose a layer of resin between the sand and the underside of the plank. Upon this under floor the top floor is laid, in the usual manner."

The cost of such floors as these is, however, considerable. To those who

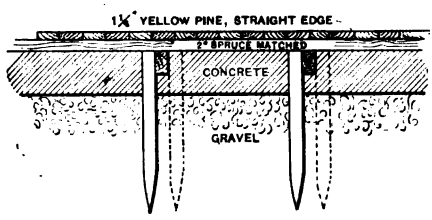


FIG. 4

desire a cheaper floor and incline to favour the preservative powers of tar, a weak cement, covered with a thin layer of tar-concrete, or mopped thoroughly with refined coal tar, may be used. The writer has had good success with the use of lime mortar. The layer of mortar should be about two and one-half inches thick on top of the earth,

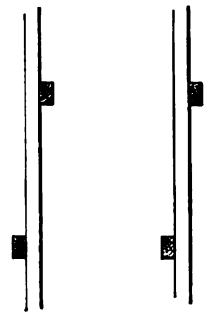


FIG. 5

and filling closely against the under side of the flooring. Since no one can remember of ever seeing lathing rotted out when covered with good lime plastering, it may be reasonably expected that such use of lime mortar would be most effective against decay. Such a floor has been in use for six years and shows but little decay on the under side of the planking, and it is quite probable that the result would be more satisfactory if a more perfect contact between the lime mortar and the planking had been secured. This floor is shown in Fig. 8, and it will be noted that in this case no wearing floor is shown. It was laid over a large shop doing heavy work and it was expected that the wearing surface of the spruce planks would last as long as the under surface would resist decay. This appears to have been the fact.

This floor was constructed as follows:—Two inch spruce plank, matched and planed on one side, are laid on three by three-inch chestnut joists, necessary in this case as no top wearing floor was laid. The surface of the earth is at all places two inches away from the wood, and this two inch space is filled with good lime mortar. After the surface of the earth has been graded, as shown in Fig. 8, with the channels for the three by three-inch joists, the latter are held in position by stakes made of strips of boards driven flat against the sides of

the joists, similar to the method shown in Fig. 5, at intervals of about three feet. These board stakes are for the sole purpose of holding the joists in laying and nailing of the matched planking.

This flooring has been down since 1896, and has given good satisfaction.

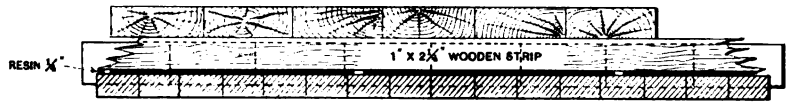


FIG. 6

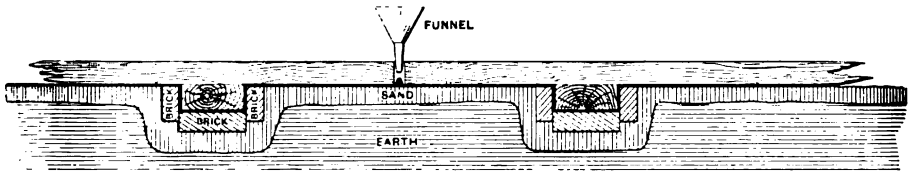


FIG. 7

place while the lime mortar is forced under them, and allowed to set or partially dry before the planks are placed.

Before the lime mortar is put in place, the earth is carefully shaped under and around the joists, so that nothing but clean lime mortar will come in contact with the wood. This mortar is filled under the joists and between them somewhat above their upper surfaces. This over-filling will allow for the shrinkage in the mortar which should be allowed to partially set before the final striking-off. This should be done, not with a straight-edge, but with an edge curving nearly half an inch in three feet, so that the under side of the planking will press firmly upon the mortar. A thin layer of dry slaked lime may be finally spread to fill any depressions, followed by the

It has kept in an even, solid condition over a large shop. From present appearances the life of this floor will be about twelve years. Probably if southern pine, oak, or chestnut, or even first class hemlock, were used instead of spruce, the floor would resist decay for a longer period, and if instead of lime mortar, two inches of tar and coarse sand concrete were used, a probably still longer life would be assured.

The cost of the flooring shown in Fig 8 should be about 85 cents, or 3s 5d., per square yard. With a top flooring of ⅞-inch maple, omitting the joists, the cost should be about $1.10, or 4s. 5d., per square yard.

A granolithic or Portland cement concrete floor, five inches thick, with top covering of Portland cement and sand one inch thick, without wood, should

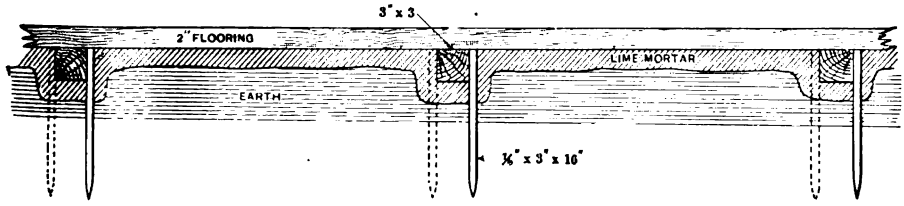


FIG. 8

cost from about $1.35 to $1.50 (5s. 5d. to 6s.) per square yard; laid with three inches of concrete instead of five, it should cost about $1.15 to $1.25 (4s. 7½d. to 5s.) per square yard. The floor shown in Fig. 1 with tar concrete foundation would cost about $1.13 (or 4s. 6½d.) per square yard. If three-inch hemlock planking were used instead of one-inch this floor would cost $1.50 (6s.) per square yard. Finally it will be seen that the special conditions of use and location of a given floor are factors which will largely determine the floor foundation to be adopted, though a continuously supported ground flooring of wood, laid on tar concrete, is believed to be beyond question the most suitable and desirable floor yet suggested for a machine shop.

THE TOOL ROOM IN MODERN WORKSHOP PRACTICE

By Wm. H. Booth

THE modern idea of a manufacturing engineers' works is that all the parts of the articles manufactured shall be made interchangeable, and that they shall be capable of being assembled on the erecting floor and of going together without hand fitting. This ideal has not yet been attained, and, in the best regulated works, there is always some final hand work necessary. In order that the end mentioned shall be approximated as closely as possible, it is necessary that the machines which do the work shall be accurate within the necessary degree of accuracy, for a machine tool can, at best, produce only copies of itself. A lathe, for example,' when set to turn a cylinder, will produce pieces as nearly circular in cross section as the lathe spindle and its bearings will permit, while the condition of the bed and of the slide rest will be reproduced in the degree of accuracy with which any cross section of the turned piece approximates to the same diameter.

Again, good machine tools are useless without the various accessories that go to form a complete outfit. A drilling machine, for example, may be a good and true-running machine, but it will not do good work unless supplied with good drills, and these will not work well unless truly ground. This demands a suitable grinding machine, and thus all machines and operations are more or less interdependent. In order fully to carry out the modern idea of manufacturing there is necessary a constant supervision over the tools employed, in order to keep them up to the highest standard of output and accuracy. This constant supervision is useless without means of putting into force the recommendations it may make. Hence arises the tool room. The idea is not new. It has been applied by the textile trades these last seventy years, and every cotton factory had its "mechanics' shop," with lathes and drilling machines and vise bench for the purpose of keeping the machinery of the factory in repair, replacing broken wheels, rebushing spindle bearings, and generally keeping everything in full order so as to secure a maximum output.

In the engineers' workshop, however, the idea did not flourish. "Why," argued the engineer, "should I set aside certain tools to do repairs when these repairs can be done just as well on the regular machines in the shops?"

This way of looking at the question naturally arose from the similarity of the work to be done both in the works and in the tool room, unlike the textile factory, where the works output was an entirely different product.

In the craze for new and improved tools that has arisen during the last few years many firms have purchased new tools without securing a corresponding benefit, and in some cases with positive loss, the idea that the upkeep of tools can be entrusted to the manufacturing staff being quite wrong. The manufacturing staff are usually men who are not skilled mechanics. They are, perhaps, excellent workers at machines, but not skilled as craftsmen, and this tool room hands must be.

In a small works the tool room must be small, but there are few works engaged in manufacturing that are not

ONE OF THE SEVERAL TOOL STORE ROOMS IN THE WORKS OF MESSRS. LUDWIG LOEWE & CO., LTD., OF BERLIN. THESE STORES ARE LOCATED IN DIFFERENT DEPARTMENTS AND EACH IS EQUIPPED WITH A PARTICULAR LINE OF GAUGES AND TOOLS FOR THE SPECIAL WORK CARRIED ON IN ITS DEPARTMENT

large enough to keep a tool room and staff of some kind. The staff may be but one man, and he may not have many tools to work; he may even have to do his work on the manufacturing tools. It is probably more important to have a tool room staff than to have the machines. The latter can be added as required and as the works grow. The staff, when not fully employed in keeping tools in condition, can utilise unemployed time in the making of small tools. This brings up the question as to how far a tool room should be expected to go in the manufacture of the small tools used in the works.

Many people make their own taps, reamers, milling cutters, and even gauges. This is doubtful economy, for such tools can rarely be made at as low a cost as that at which they can be purchased from regular makers more fully provided with special plant for producing small tools and suitably hardening them. The tool room should be equipped with the best possible machines, and the man in charge must be a thoroughly good mechanic.

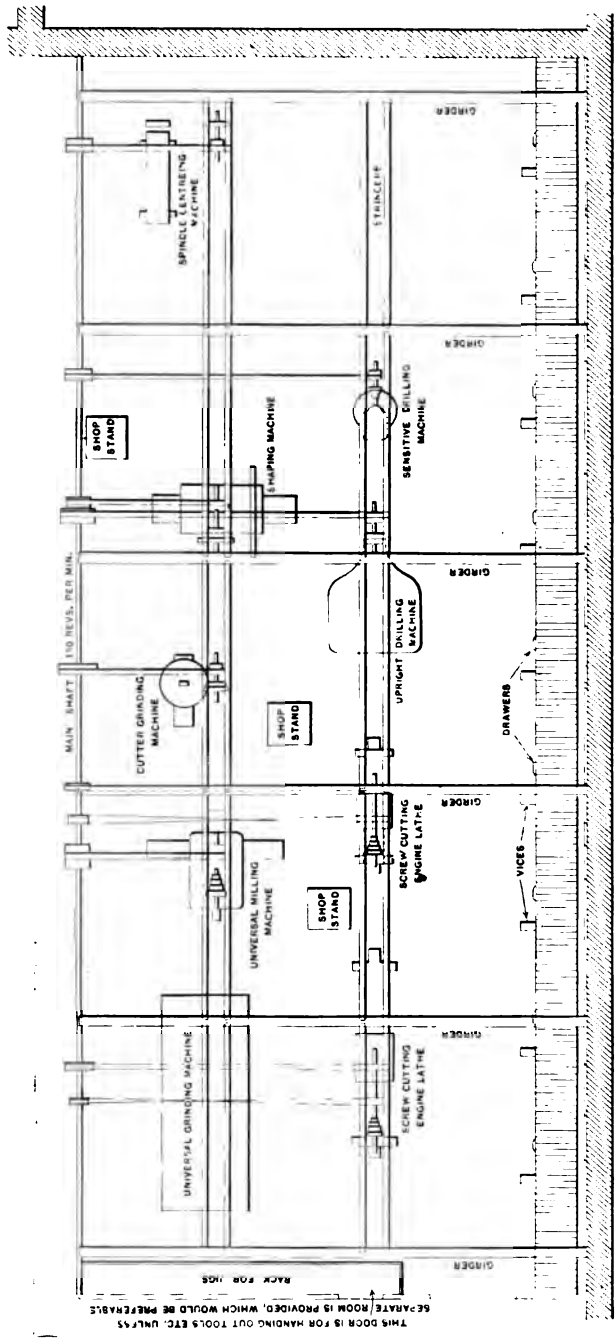
The tools must be suited to their work and not necessarily of a manufacturing type. The work which they are called on to do is the repair of the manufacturing tools and the making of special small tools which are not found in manufacturers' catalogues; of special gauges required in the particular work done in the shops; and of templets and jigs.

The manufacturing engineer who wishes to turn out articles cheaply and well should consider first the range of sizes he must adopt. As a rule, the number of sizes is too great. Given a series of diameters ½", ⅝", ¾", ⅞", and 1", is not this fully sufficient for most regular engine work without introducing $\frac{9}{16}$", $\frac{11}{16}$", $\frac{13}{16}$," and $\frac{15}{16}$", thereby involving so many more sets of drills, gauges, etc., at an unnecessary expense? Where a piece is made in large numbers and is in constant demand, the jig in which it is fixed to undergo various operations in drilling will be provided with a full set of boring bars, drills, and reamers, all regularly set up for that particular piece and never dismantled. In this way large numbers of tools are, in a sense, locked away, and it is a question for the tool room to determine to what extent this system can be carried; at what point in regard to the number of pieces made in a given time it is justifiable thus to lock up tools for a certain portion of the year in idleness; and when to break up the setting up and use the tools on other work, thus involving the expense of resetting the special lines of tools.

It is the duty of the tool room to take in hand the article to be manufactured in the works, dissect it, consider each part, and lay out the process by which such part shall be made, preparing the necessary tools wherewith to make it, and devising suitable jigs and other fixtures. In the case of new designs there should be consultation between the tool room and the drawing office as to the best form in which parts should be made, in order to admit of the best and cheapest mode of manufacture.

At one time it was occasionally the habit of the drawing office, and it may be so still in some places, to set puzzles in construction for the patternmaker and foundry man to surmount. No doubt such puzzles served to make life and work interesting all round, but they were not paying investments. Too much attention can hardly be paid to the simplification of designs in order to facilitate production with the smallest possible value of special tools or jigs. When expensive machine tools have been purchased, they may be practically reduced to the value of the old tools they replaced simply for lack of suitable tools to go with them. An extreme case, to use merely as an illustration, would be the purchase of an automatic screw machine without special tools being provided for the parts to be made. Such special equipment and its upkeep fall to the lot of the tool room to make and maintain.

In the course of its duties it will naturally fall to the lot of the tool room also to determine when a manufacturing tool should cease to be maintained in good repair and should be transferred to the scrap heap or the dealer's store. To it



PLAN OF A TOOL ROOM ARRANGED FOR A LARGE ENGINE SHOP. THIS SHOWS THE DISPOSITION OF THE VARIOUS TOOLS, BENCHES, AND SHAFTS

also falls the determination of the economy of new methods, as, for example, grinding as a means of finishing parts that have hitherto been finished by simple turning.

Obviously the main object of a machine tool is to remove surplus material as rapidly as possible, but a machine that is best fitted to remove surplus stock with rapidity is not likely to be capable of accurately finishing a piece to size. A lathe may have become so worn by hard work that it can no longer do accurate work. The question then arises, Shall this tool be replaced by another similar, but new, tool, or shall the old tool be retained for the rough work and the finishing be done after the new method by the grinder? Such a question demands careful consideration, and the answer is eminently within the province of the tool room.

Generally the tool room must confine itself to special work and should avoid the making of all standard articles. Its equipment must include sets of gauges and reference gauges to prove the working gauges of the establishment. In the highest class of works the provision of gauges is very liberal.

In commencing a tool room it should be remembered that it will, if properly worked, prove an influence for good throughout the whole establishment. A central authority in charge of tools will exercise an influence on the care of tools in the shop. The care of fine cutters demands such accessories as shop stands and a general attention to cleanliness and tidiness and good fittings.

As regards the provision of the tool room machines themselves, these, in a well-established works of good size, will include a centering machine to drill centre holes in all pieces to be held in centres; a fully equipped 6-inch or 7-inch screw-cutting engine lathe; a universal milling machine; a friction drive shaper; an upright drill and a small drill of sensitive type; and also a cutter grinder with necessary attachments for various forms of cutter. A lathe to back off formed cutters is usually necessary, and it may serve the purpose of the lathe above where there is not scope for the two machines. This list may be expanded as the use for further tools shows itself. Often less must be attempted, the manufacturing machines being used when required for tool room purposes by members of the tool room staff.

The small equipment of the tool room, in addition to plain gauges, should include thread gauges and full sets of taps and arbours, hobbing taps, etc., and also Morse taper gauges. The tool room is the place where standard gauges will find their proper field, the gauge for the manufacturing department being the limit gauge.

Closely connected with the tool room is the tool store, which is not to be confounded in any way with the tool room, but is under the care of this. The duty of the tool store is to give out to, and receive tools from, the workmen, to test and inspect the tools before putting them into their places, and to grind them and generally maintain them or see to this being done. Thus, the tool store is a branch of the tool room and depends on this for maintaining its stock in order.

It should fall to the tool store to work in conjunction with the inspection department in maintaining the workshop gauges in order. The inspection gauges are watched by the tool room, and the inspection department reports when the work of any man begins to approach its outside limits of tolerance, and this report should be passed to the tool stores and shown by the stores to the workman as authority for handing him a fresh gauge and removing that which is becoming incorrect. Thus a fully matured tool room system works in harmony with the tool room and with the inspection table, thereby keeping in sight, through the medium of the finished work, both the machine tools and the smaller accessories and maintaining these in the highest order, as well as in numerical sufficiency.

Generally, the tool room as the basis of manufacture aims to secure accuracy, quality, and efficiency by a rigid maintenance of labour-saving machinery and proper upkeep of cutting tools. In the

old system, where a new shop started up with good and new tools, there was a steady and progressive deterioration of these tools and good work was done only by skilled workmen, but at greatly enhanced cost. The old shops did work that was both sound and good; but its cost was greater than it should have been, and often only tolerable because man and machine had grown old together and the man could get good work out of a machine that would puzzle a new man to work satisfactorily. These casual methods are replaced by certainties in the modern system.

The tool store may be located actually in the tool room itself, though this is not necessary; indeed, it is not even desirable. One tool room is sufficient for a large works, but there may with advantage be several tool stores, located in the various departments. On page 246 is shown the tool store room of a large machine shop. This is one of several tool stores in the same works, and will serve to give a general idea of the method of fitting up such a store so as to be as convenient as possible to the workmen and as little of an obstruction as possible.

A light wooden structure with wire netting above forms a suitable room. Where there are several tool stores in one works a convenient register of each should be available in the other rooms in order that a shortage in one store shall be made up from the others by a proper system of transfer. When any particular tool is too frequently in requisition for the number in store this should be increased in numbers.

A plan of a tool room arranged for a large engine shop is given on page 248. This shows the arrangement of the various tools, benches, and shafts. This is not given as a best possible design, for, as must often occur in an already established works, the best had to be done with the only site available.

It is certain that without a properly equipped tool room no manufacturing establishment can long continue to produce good and interchangeable work. In all works that employ machinery and tools there is a decided tendency towards retrogression and degeneration, and this can be kept in check only by means of a special department whose particular duty it is to maintain tools up to the high-water mark of efficiency.

The aim of the workshop is entirely different. It is to produce a maximum output at a minimum of expense, and the effort to do this exerts a more or less severe pressure on the workmen to produce things that will pass muster. When a man is thus producing articles to be like a certain original he copies that original as closely as he can in the shortest time and runs more or less risk of his copy being condemned as too inaccurate when it is sent to the inspection department. Hence comes the unsuitableness of standard single dimension gauges for workshop practice and the substitution of limit gauges which, while allowing a certain inaccuracy that is inevitable in all work, compel such inaccuracy to be less than the tolerance provided in the two dimension or limit gauge. But this matter is treated of more at length under a separate head elsewhere in this issue.

MODERN FOUNDRY APPLIANCES

By Dr. Richard Moldenke

IT is a hopeful sign for the foundry industry that the designer of special machinery is now cordially welcomed in it. This is primarily due to foundrymen's associations, which have brought together those in the trade who are willing to concede that others know something also, and have stimulated investigation to settle much-mooted questions. They have facilitated the exchange of ideas and experiences; have indicated new openings for the foundry product; and have given competition a healthy tone.

The old-fashioned founder who thinks this progressive movement unnecessary and will not profit by it, is having the specialty work taken away from him. He finds enough to think about in watching the regular procession of moulders who are acquiring geographic knowledge via his shop, remaining a pay day or two. In hard times he has two small heats a week, and in the good, he asks any price the customer will stand for the "hurry up" jobs he gets.

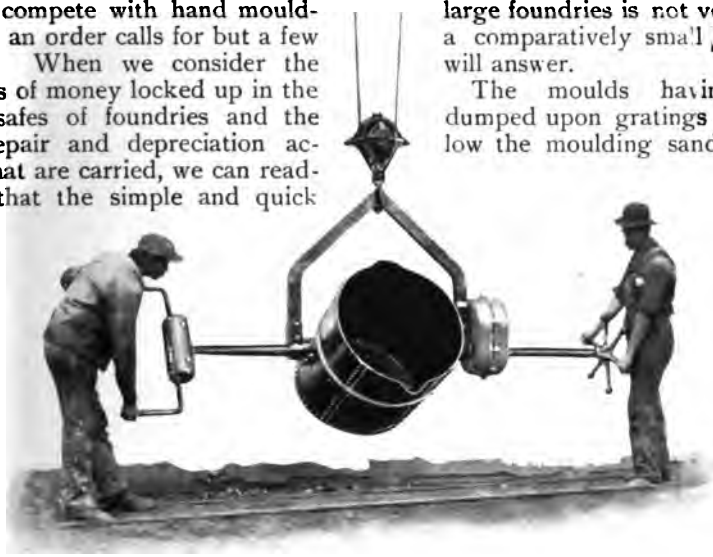
It is where thousands of castings of a kind are made that we find modern conditions aimed at. In the industrial war between nations, now becoming more and more acute, this will count heavily, for now that inventive genius has been directed into foundry channels, we find British, German, and American trade journals full of suggested improvements, as well as actual accomplishments in the line of rapid and cheap production of castings.

In general, modern foundry appliances can be divided into two classes, —those intended for specialty shops, designed to carry out the work under the conditions prevailing at the places for which they are built, and those which are applicable in every foundry. Thus, in the first-named division we find the various kinds of moulding machines, among which we may even include the snap-flask and the squeezer, for these are essentially modern from the fact that they are now being applied in the production of castings formerly

A CRANE TRUCK FOUNDRY LADLE MADE BY THE WHITING FOUNDRY EQUIPMENT CO., HARVEY, ILL., U. S. A.

MACHINE MOULDING FLOOR IN THE FOUNDRY OF MESSRS. SULZER BROTHERS, WINTERTHUR, SWITZERLAND

thought wholly outside their scope. From moulding up *S* wrenches and pipe fittings by machine we have progressed to car bolsters, car couplers, gears, pulleys, and many intricate specialities which on occasion we also find in the regular jobbing foundry. The greatest improvement to be made in the moulding machine will lie in the cheap and rapid application of ordinary patterns to them, opening a field for this foundry appliance wherein it can successfully compete with hand moulding when an order calls for but a few castings. When we consider the vast sums of money locked up in the pattern safes of foundries and the heavy repair and depreciation accounts that are carried, we can readily see that the simple and quick application of a pattern just made to a machine which preserves it from the abuse it would otherwise get represents a material economy.

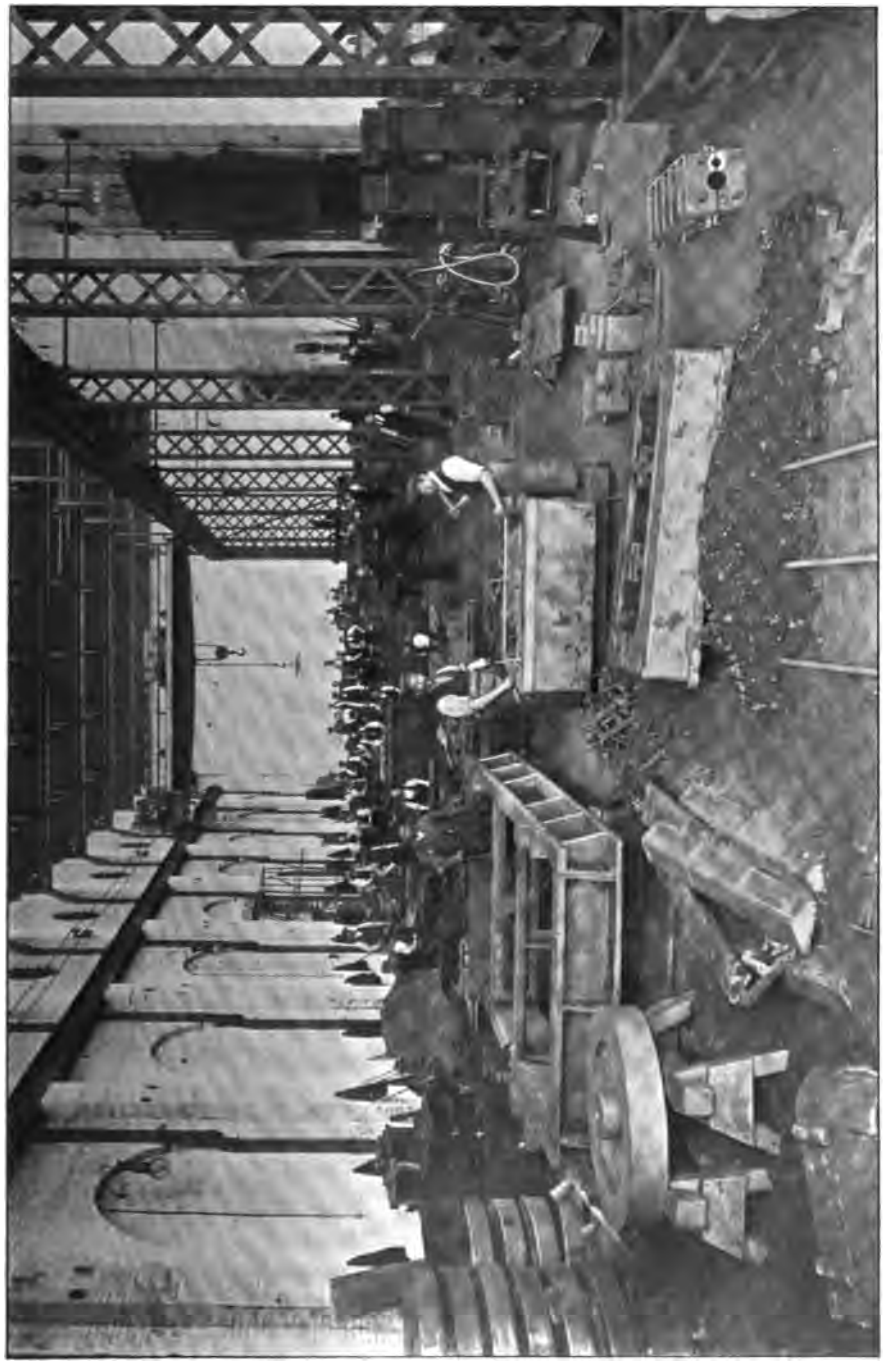


A FOUNDRY LADLE MADE BY THE C. W. HUNT CO., NEW YORK

In the category of foundry appliances for specialty work would come the elaborate, but highly efficient, sand tempering and conveying systems now installed in some of the largest manufacturing foundries. The general arrangement would be as given below. One will, however, never find the system to be described complete in any one plant, especially when connected with a casting conveying apparatus. The reason for this is probably the great first cost, which is often higher than that of the whole plant before its installation. The typical case would be as follows:—Beginning at the sand sheds, preferably located under the railway siding, a suitable conveyor takes the new sand required into the foundry, being timed properly and so arranged that various grades of sand may be handled as wanted. The sand arriving in the foundry is dumped through a grating into the old sand as this goes through the tempering process. As the amount of new sand used daily in even the very large foundries is not very great, a comparatively small conveyor will answer.

The moulds having been dumped upon gratings which allow the moulding sand to drop through, this falls into a trough or other conveying system which carries it to the point at which it undergoes the various processes necessary to render it fit to mould with again. The first thing required now is to remove the shot-iron present. This would seem best accomplished by means of a magnetic separator. Next comes some system by which the lumps of sand are crushed. A pair of wide rolls answer this purpose very well. Just below the rolls, as the sand drops down, a spray of water can be introduced and adjusted to the amount required. This would then give us the sand free from iron, fine, and damp. But it is not evenly tempered, and hence the whole

MOULDING SHOP FOR HEAVY CASTINGS AT THE WORKS OF MESSRS RODEY & CO., LTD., LINCOLN, ENGLAND



A FOUNDRY VIEW AT THE WORKS OF MESSRS. WILLANS & ROBINSON, LTD., RUGBY, ENGLAND

TRANSFERRING A PORTABLE CRANE FROM ONE POST TO ANOTHER BY MEANS OF ONE OF THE OVERHEAD CRANES IN THE FOUNDRY OF THE GENERAL ELECTRIC CO., SCHENECTADY, NEW YORK

mass is passed through a large centrifugal mixer which deposits a thoroughly uniform and well-tempered material into the vertical bucket conveyor, which, in turn, discharges it upon the preferably reciprocating trough conveyor provided with chutes from which the moulding machines are fed.

A conveyor to carry the moulds from the machines, or floors, if you like, to the casting room, either to be filled directly at the cupola by the pouring gang or set down on the floor until furnace iron is available, takes care of the output of the moulders or machine men. A travelling sidewalk should accompany the mould conveyor in order to facilitate the setting of cores, as well as to allow the moulds to be poured safely while still moving with the conveyor. The return of the mould conveyor redistributes the bottom boards and flasks or shells, depending upon the method of moulding used.

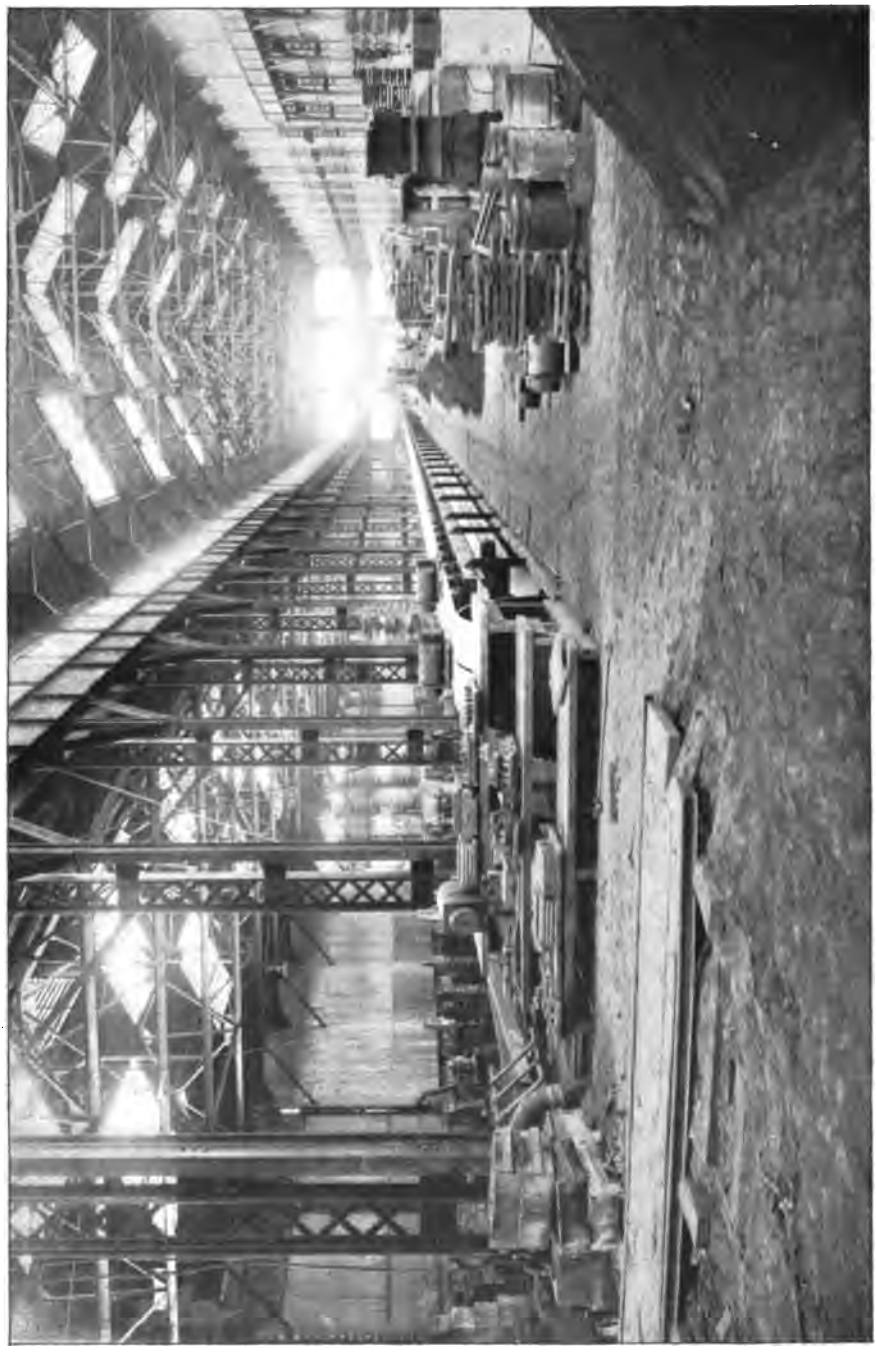
A conveyor for castings, arranged for along the grating upon which the

moulds are dumped, can take the work of the foundry, as soon as it is cool enough, into the trimming room, where it is prepared for the rolling barrels. The sand then goes through the regular routine again, the new sand either coming in after the old has passed the magnetic separator, or, if brought in by wheel-barrow, being dumped through the gratings with the old sand.

The conveying system can be extended to take in the work incident to the handling of the castings between the rolling room and the subsequent processes. Especially in the finishing rooms is a good endless sidewalk very desirable, or, better still, where the castings are small, an endless steel belt, bench high. The grinding wheels, chipping benches and finishing machines of the required kinds, etc., can all be arranged to allow the work to be taken off the conveyor, the process completed, and the work returned to travel further. Suitable storage facilities will take care of possible congestions, and the warehouse or shipping office may be made the final destination.

The great advantage of such a system is the eternal vigilance required by all hands connected with this part of the plant. The principle involved is the immediate turning over to the next man of the partly completed work, thus assuring a rapid passage through the shop. With malleable castings, the introduction of the annealing department widens the scope of a good conveying system very considerably. Then, again, the transportation of the cores from the core room, by either elevator and conveyor or conveyor alone, forms another application of a modern foundry appliance which quickly returns the money expended. Be it understood that to save one labourer the year round it pays to invest about $2000 (£400). How many labourers will one find about a

ANOTHER VIEW OF THE SULZER FOUNDRY, SHOWING, AT THE LEFT, A TRAVELLING JIB CRANE, AND, IN THE FOREGROUND, ROPE AND FLY WHEELS SWEPT IN LOAM



A STEEL BELT CONVEYOR IN THE FOUNDRY OF THE PENNSYLVANIA MALLEABLE CASTING CO. AT MC KEESPORT, PA. INSTALLED BY MESSRS HEYL & PATTERSON, PITTSBURGH, PA., U. S. A

foundry of some size who could be thus profitably dispensed with?

The various appliances about the power plant of a foundry which help cut down the running expenses need not be mentioned here. Any modern plant equipped with coal and ash handling machinery, or a gas engine plant with electrical transmission of power, will illustrate the point. The travelling cranes, however, can be made to yield splendid returns if provided with the smaller appliances for hoisting copes advantageously, for picking up large castings or cars full of small ones quickly. The best results will come with two cranes on the same run-way, each having two trolleys, or, in other words, four hooks available at the same time. These, with several jib cranes, and provisions on the walls or columns of the foundry to quickly attach them by the travelling cranes, gives the maximum of efficiency here. A double-cage system for the cupola hoist, arrangements to pick up a furnace charge from the foundry floor with the crane and place it upon the furnace platform, will handle the material to be melted with advantage.

The core ovens may be provided with many an appliance which will facilitate the quick observation of the material within, allow a shelf-full to be withdrawn without interfering with the continuity of the heat, and be so provided with flues and dampers that the temperature within may be sufficient to thoroughly dry, and yet be perfectly uniform, too.

The cleaning facilities of the modern foundry have been augmented by the sand blast. British and Continental practice has been ahead of American in this respect for some time, many shops in Great Britain, Germany, and Switzerland using this method of cleaning almost exclusively. Americans rather object to the too excellent cleaning of the castings. Too much poor moulding is shown up by it. On the other hand, the introduction of the sand blast has been a boon to the enameling industry, for the surface of a casting is left perfectly clean and especially free from graphite. The introduction of hydrofluoric acid for pickling purposes is also a decided advance, the sand on the casting being dissolved, and not the iron under the scale, as when sulphuric acid is used.

Iron interchangeable flasks, core machines for making the round stock cores now seldom provided for by making special core boxes, moulding appliances which make use of sweeps, and core appliances working on the same principle are only some of the many devices which help to make up a goodly sum total of money saved during the year.

It is the aim of every foundry foreman to get up useful contrivances in connection with the jobs he has in hand, and these soon become part of the institution. In going through the various foundries one often sees a device for saving labour and insuring accuracy which commends itself at once. Given the larger appliances furnished by the establishment, these useful kinks frequently double their value.

To-day, more than at any time, the cry is for increased production at lower costs, and well-devised shop-cost systems in the office soon show where a modern foundry appliance is wanted. The engineer has placed at the disposal of the foundryman labour-saving appliances which can find application in every part of his establishment, and his will be the fault if advantage is not taken of them.

CYLINDRICAL GRINDING MACHINES

WITH SOME EXAMPLES OF GERMAN AND AMERICAN DESIGN

By J. E. Frantz

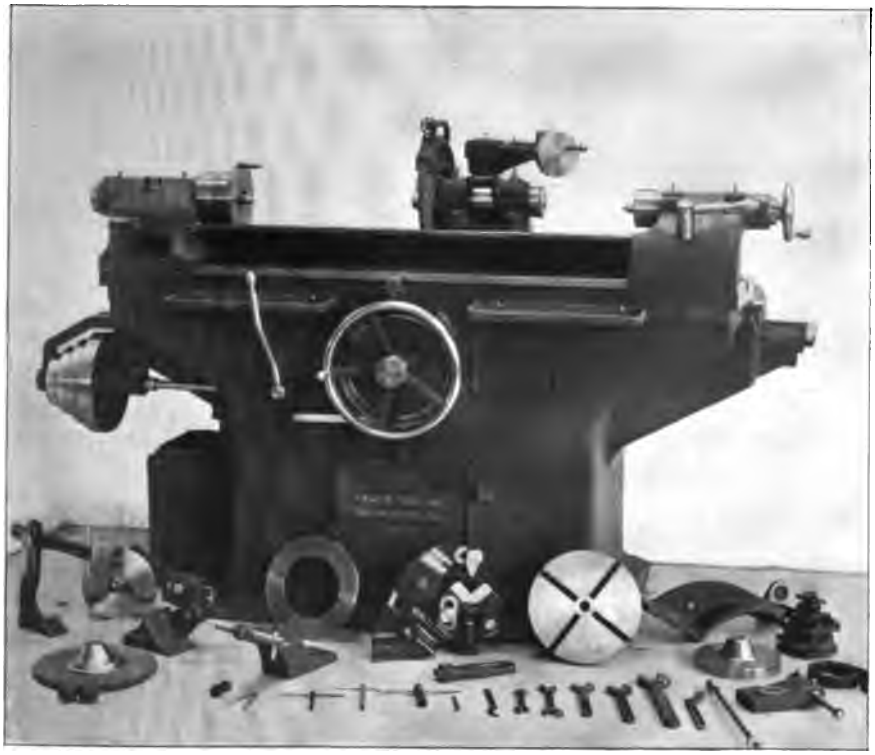
IMPROVEMENT in methods in machine shop practice is due mainly to the desire to build more accurate machinery than before and to the necessity of reducing the cost of product, and one result of efforts to secure this accuracy and reduced cost of finishing hardened parts has been the grinding machine. This machine might properly be termed a grinding lathe, and its function is to finish, by abrasion, shafts, spindles, tools and other pieces, removing stock by using a grinding wheel composed of some suitable material, such as emery, corundum, or carborundum.

The lathe has been the machine for finishing cylindrical work. In its primitive state it was indeed crude, and for many years was the only tool suited for finishing this class of work, but the quality of finish and the accuracy demanded to-day cannot be obtained with it. The idea of using an emery wheel on the tool post of the lathe was, doubtless, suggested as a means for finishing hardened shafts, and from this original plan there was devised the first grinding machine. It was a light, delicate tool, and its proportions were, no doubt, suggested by the class of work it had to finish. As the method became recognised, further improvements in the tool itself were made and its application to larger parts readily followed, so that the various grinding machines now manufactured are capable of finishing a large variety of work, from small spindles and shafts to heavy engine shafts, rolls, etc. The present type of grinding machine will size with accuracy cylindrical, conical or plane face work of hard or soft steel; cast iron, soft or chilled; brass, copper, rubber; and, in addition, will grind the sides of saws and cutters, and with special attachments can be made to perform many other operations in manufacturing or tool work.

There are at present two distinct types of grinding machines,—one in which the centres carrying the work have fixed positions while the carriage on which the grinding wheel is located traverses; and the other in which the grinding wheel remains in a fixed position, so far as longitudinal movement is concerned, and the carriage, on which the swivel table with the work-carrying heads is located, is the moving part. A general description of one type explains the operations of both.

The machine itself consists of a base on which is located a swivel table carrying the work centres and guides on which a carriage traverses and upon which a base carrying the emery wheel is located. To drive the mechanism properly an overhead countershaft is arranged so that the proper changes of speed may be given to the emery wheel or the work, and to stop the work independent of the emery wheel. This latter result is accomplished by the use of a clutch which can be engaged or disengaged as desired. The traversing mechanism is also arranged to stop independent of the work and wheel. By means of this arrangement it is possible to revolve the part to be finished at the proper speed. The usual practice is to have the peripheral speed of the work about 75 to 100 feet per minute.

The table which carries the centres is arranged so that it can be swiveled for the grinding of taper parts, while



A UNIVERSAL GRINDING MACHINE MADE BY THE LANDIS TOOL CO., WAYNESBORO, PA., U. S. A.
TWELVE INCHES SWING AND 42 INCHES BETWEEN CENTRES

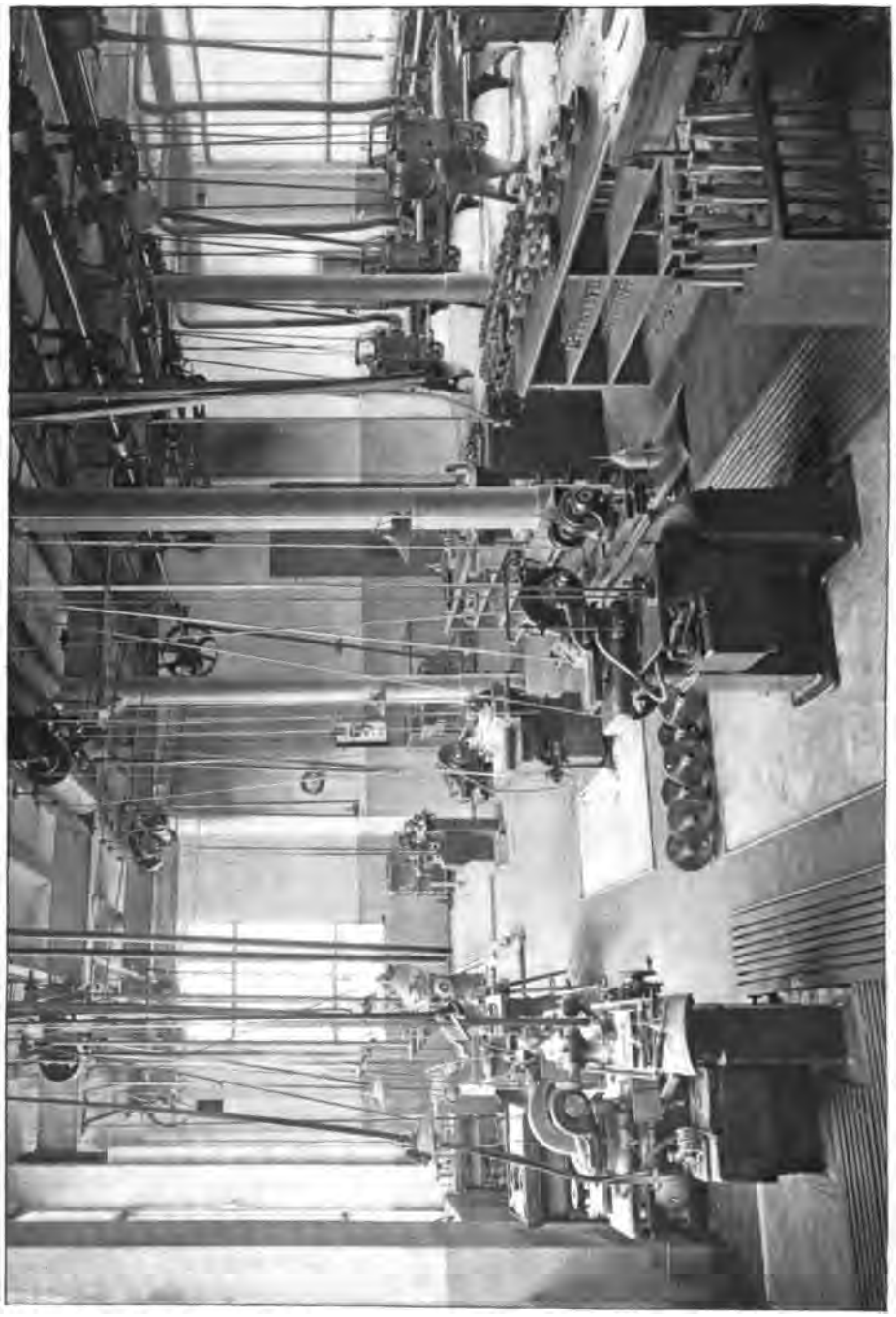
the headstock spindle, to which chuck and face plate can be attached, swivels also for grinding short tapers externally or internally or for plane face surfaces.

The slide, on which the base carrying the emery wheel is located, has a swiveling movement, and the wheel base, resting on top of the slide, is also free to swivel. This permits the grinding of short angles on shafts, as by swiveling the slide to an angle of, say, 10 degees, a shoulder of this angle can be ground. For the setting, accurate graduations are provided, and the production of any angle desired may be readily attained.

The travel of the emery wheel or the work, as the case may be, is automatically reversed, and the dogs controlling the reversing points are easily changed from one position to another. For feeding the emery wheel to the work an automatic device is arranged so that each reversal of the carriage brings the wheel to the work, taking off the amount desired from 0.00025 to 0.005 inch in diameter.

For the finishing of shafts, spindles, and such other parts as can be carried in centres, the head stock spindle does not revolve. In this manner accuracy is produced, as the quality of the work does not depend on perfection in the centre or in the driving spindle, as would be the case in a lathe where one live centre and one dead centre always are used. With a grinding machine on all suitable work dead centres are used; the live spindle is used only for work that has to be carried in a chuck or face-plate.

The tail stock spindle is made to operate under a spring tension, constructed so that the centre may be solidly seated should any change occur in the work being operated on, due to



GRINDING DEPARTMENT IN THE MACHINE SHOP OF MESSRS. LUDWIG LOEWE & CO., LTD., BERLIN. ABOUT FIFTY GRINDING MACHINES ARE EMPLOYED. AT THE RIGHT, SURFACE GRINDERS ARE SHOWN, WITH EXHAUST PIPES FOR REMOVING EMERY DUST

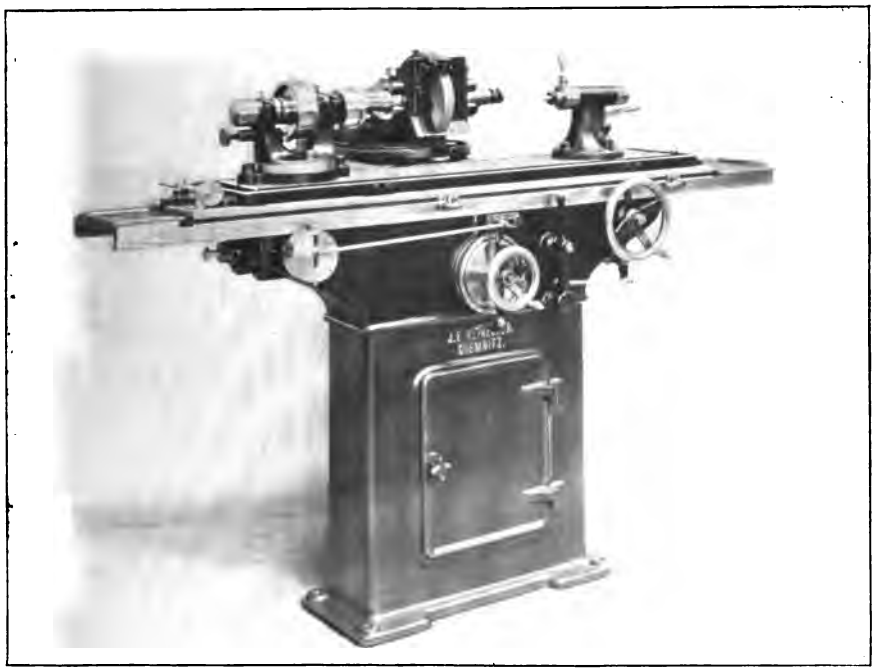
change of temperature. It is also arranged so that it can be clamped solidly when desired.

For properly supporting the work to prevent chattering and springing, suitable rests are provided. These are arranged so that the support comes under a spring tension or can be rigidly secured in any fixed position. The character of the work to be finished determines the number of rests that have to be used.

The automatic cross-feed for the emery wheel is arranged to stop at any point at which it is set. In the case of sizing shafts, the first one is made the proper diameter and the automatic cross feed is properly set. All future pieces will then be ground to these same dimensions less, of course, the wear of the wheel, which usually is very slight. To compensate for the wear of the wheel a small lever is pressed as many times as the work is too large in one-quarter thousandths. The improvements which have been made in grinding machines in the last few years are represented by additional weight, increased size of emery wheel, spindle, etc., and a more thorough provision for the use of water. As now constructed, a copious supply of water can be used without reaching the finished parts of the machine. It is advisable that this should be so, for a great amount of water is necessary to carry off the heat generated by the emery wheel.

It has been the custom with many to use soda water for keeping the parts cool, but the soda was added merely to prevent rusting of the machine. With the later improvements and the better devices for caring for the water used, fresh water has been found very desirable. In fact, hydrant service is in many cases preferable, for the reason that the water, and consequently the filth, is not returned and retained on the machine.

The foregoing description applies principally to the type of machines known as universal grinding machines.



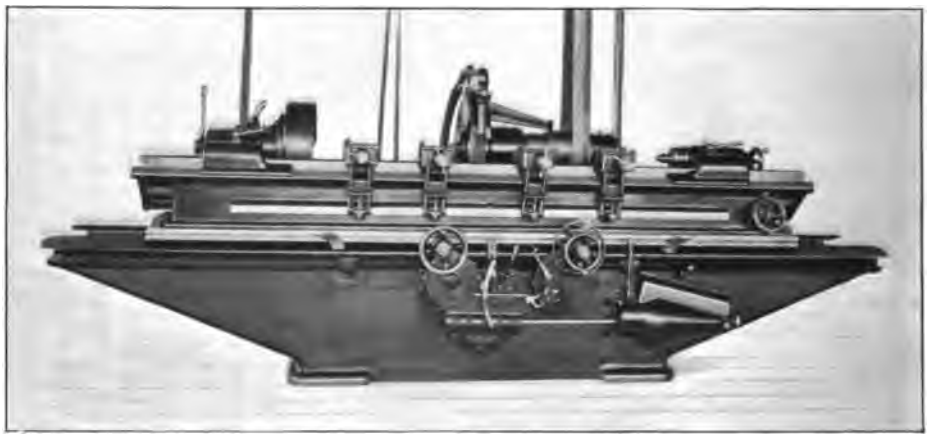
A UNIVERSAL GRINDING MACHINE MADE BY J. E. REINECKER, CHEMNITZ-GABLENZ, GERMANY

As the saving effected by these tools became apparent, the demand for something of a more simple construction was created. On the universal machines there are provisions for a large variety of work, not necessary when a manufacturer uses a number of these tools, for the reason that a large volume of work to be finished is straight or taper parts. No short angles are to be ground nor holes finished. The plain grinding machine was, therefore, built, and in it there are not incorporated the swiveling adjustments to the wheelbase nor to the head stock. The size of the emery wheel also is increased so that it is more efficient, but the means for operating the machines are practically the same.

The cylindrical grinding machines were originally used for finishing small parts, such as hardened tools, spindles, etc. As the method became recognised, the demand for heavier tools increased, and machines adapted for such service were provided. For the handling of heavy pieces it is very desirable to have machines located under a crane, and to meet this condition self-contained machines were devised.

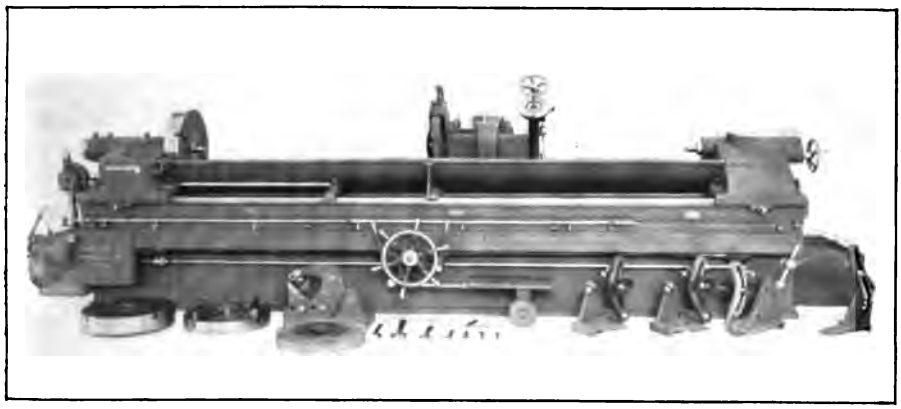
The earlier practice with parts to be finished by grinding was to finish the shaft, spindle, or other part on the lathe to as near the required size as possible, say, to 0.005 inch or 0.006 inch, and then to grind. In removing a small amount of material the grinder corrects the errors of the lathe. The lathe tool might, and would, leave high spots, due to the steel not being homogeneous, while the grinder would not leave such places, because, should the tendency of this machine be to follow the shape of the work left by the lathe, the last cut being so very light would practically eliminate the influence of one part of the shaft being slightly harder or even a great deal harder than others.

This method was an improvement, as it enabled manufacturers to produce accurate parts at a cost at least no greater than before; but it did not give to them means by which they could reduce costs. With further improvements in grinding machines it is now found that to operate on a shaft in the rough, say 1-16 inch to ¼ inch above the finished size, it is necessary only to take one rough cut on the lathe. This will bring the part to within 0.015 inch or 0.020 inch of the finished size, and the remainder can then be economically removed on the grinding machine.

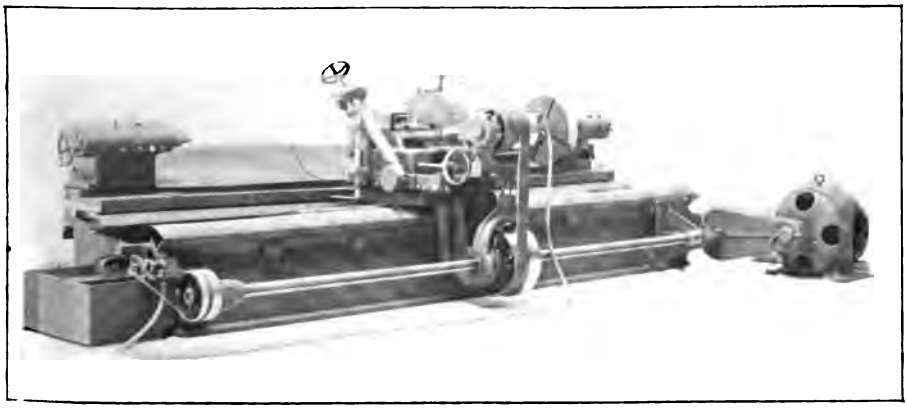


A PLAIN GRINDING MACHINE MADE BY THE NORTON GRINDING CO., WORCESTER, MASS.

The use of grinding machines was originally confined to makers of fine tools, but gradually their service has extended to almost every branch of the machine trade, from the finest tool work to agricultural implements, and, in quality of work produced, from an ex-



AN ELECTRICALLY-DRIVEN GRINDING MACHINE MADE BY THE LANDIS TOOL CO., WAYNESBORO, PA. TWENTY-SIX INCHES SWING, 12½ FEET BETWEEN CENTRES

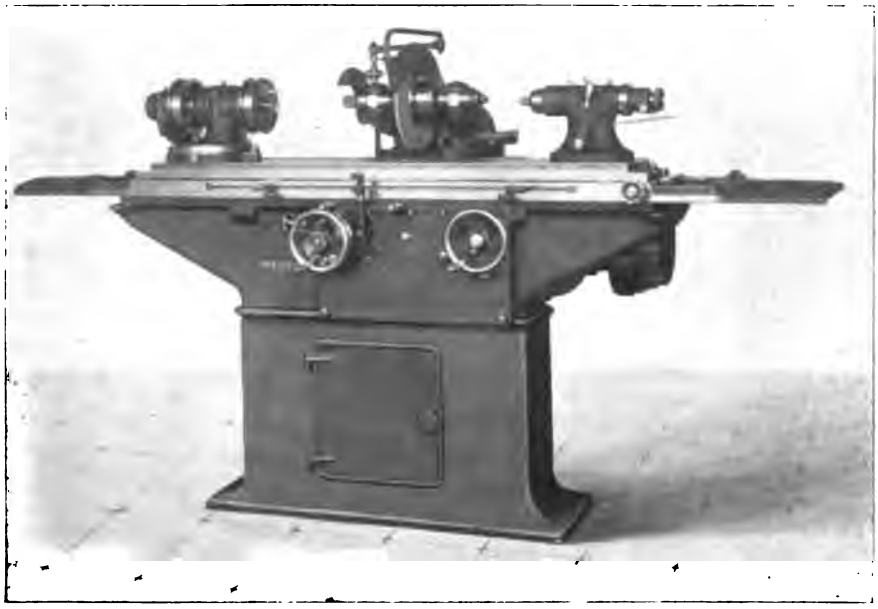


ANOTHER VIEW. THE ELECTRIC MOTOR DRIVES THE MACHINE BY MEANS OF A RENOLD CHAIN

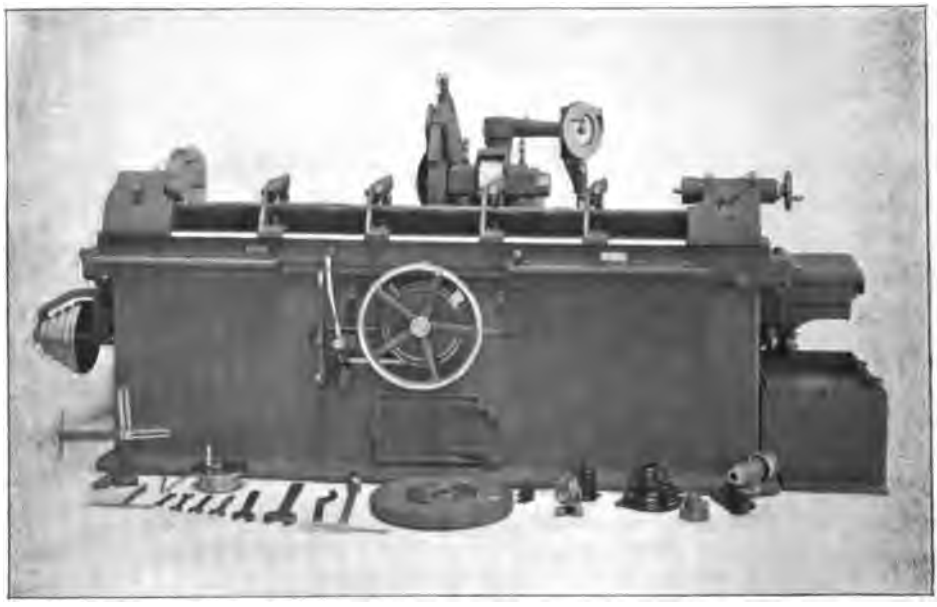
act sizing of parts to simply truing-off rough castings.

In preparing parts to be finished on grinding machines the best practice is to take one rough cut on a lathe with a feed of ⅛ inch to 1-12 inch per revolution and approaching as nearly as possible to the size the piece is to be finished. It will be found that the part will then ordinarily measure from 1-64 inch to 1-32 inch large over the tool marks. Many users of grinding machines find, by adopting a size of from 0.005 inch to 0.008 inch below the standard measurements, that cold drawn steel may be advantageously used for some parts of their machines, and there are also many cases where finishing castings without first turning them is a practicable and an economical method.

The grinding machine is a time-saver in the fitting of parts. On the lathe, shafts or pins, straight or taper, that have to be fitted to bored or reamed holes, require care and time to be brought to the correct size without several trials. The first cut might bring the piece to within 1 64 inch of the proper size, and then another cut would enable the operator to make a trial of his job. If not quite right, the file will have to be used or another light cut is necessary, and each additional cut requires just as much time as the original, even though



A UNIVERSAL GRINDING MACHINE MADE BY THE BROWN & SHARPE MFG. CO. PROVIDENCE, R. I., U. S. A.



A PLAIN GRINDER MADE BY THE LANDIS TOOL CO., WAYNESBORO, PA.

the amount that has to be removed does not exceed 0.002 inch or 0.003 inch.

In using a grinder, the first rough cut would be taken in the ordinary way and then the part to be fitted would be ground. About one-half the time will be required to reduce the 1.64 inch than is expended on the lathe, and besides, if the piece is not quite right,—say, 0.001 inch or 0.002 inch too large,—the grinder will take this off in about one-quarter of the time required by any other method. This applies also to the making of driving fits, as the size can be determined and accurately produced more easily and rapidly by grinding than on a lathe.

In lathe finishing, a shaft or spindle in which a keyway is to be cut will have to be sized first; then the keyway will be cut and the shaft straightened, and while the job may be a fairly good one, it cannot be accurate. In grinding, the sizing will be the last operation, insuring a perfectly round, straight shaft, correctly finished in less time than an inferior job could be procured by methods which had been practiced before grinding machinery was introduced.

The following examples show the time required to finish parts of different materials and sizes. These will give the reader an idea of the saving to be effected by using grinding machines. In many cases it represents a reduction of cost in finishing of 25 per cent. to 90 per cent.:—

Hardened steel taper pin, ½ inch diameter, 3 inches long, reduced 0.012 inch, finished and fitted, 3 minutes.

Cold drawn steel sewing machine shaft, ½ inch diameter, 13 inches long, reduced 0.005 inch and finished, 3 minutes. Accuracy limit, 0.00025 inch.

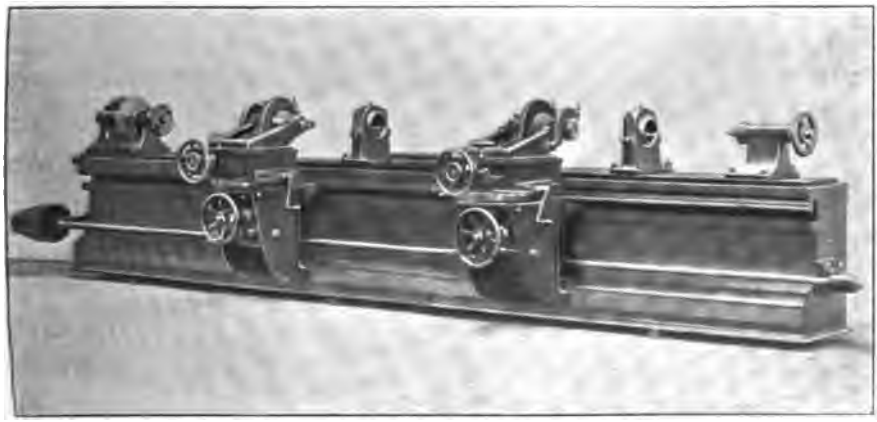
Crucible steel lathe spindle, 52 inches long, six sizes, largest 4¾ inches diameter, smallest ⅜ diameter, reduced 0.02 inch and finished, 1¼ hours.

Cast-iron pump plunger, 3¾ inches diameter, 28 inches long, reduced 0.018 inch, and finished, 12 minutes.

Brass pump plunger, 5 inches diameter, 42 inches long, reduced 0.015 inch; time, 25 minutes.

Cast-iron roll, 3 inches diameter, 22 inches long, reduced ⅛ inch diameter from the rough casting; time, 15 minutes.

Cast-iron face-plate, 8 inches diameter, removed 0.015 inch from the face; time of finishing, 8 minutes.



A MACHINE FOR GRINDING SHAFTS UP TO 16½ FEET IN LENGTH. BUILT BY J. E. REINECKER CHEMNITZ-GABLENZ, GERMANY

Cast-iron pulley, 6 inches diameter, 3 inches face, finished from the rough; time, 5 minutes.

Cast-iron spiked roll for corn husking machine, 3 inches diameter, 32 inches long, reduced 3-16 inch from the rough; time, 16 minutes.

Corliss engine valve, 5¼ inches diameter, 28 inches long, reduced 0.045 inch; time, 15 minutes.

Corliss engine valve, 6 inches diameter, 50 inches long, reduced 0.045 inches; time, 25 minutes.

Piston rod, 5 inches diameter, 72 inches long, reduced 0.018 inch; time, 1½ hours.

Hammered steel connecting rod, 8½ feet long over all, reduced 1-32 inch on round portion, 5½ inches diameter, 4 feet long, and circular surface of flat ends, 3 feet long; time, 1¾ hours.

Hammered steel crankshaft, finished surface 16 inches diameter, 7 feet long, amount of reduction 1-32 inch; time, 4 hours.

Many more illustrations of the saving in time effected by finishing on a grinder might be cited, but no doubt sufficient have been noted to enable the reader to judge of the value of such tools.

HEATING MACHINE AND OTHER LARGE WORKSHOPS

THE ADVANTAGES OF THE FAN SYSTEM

By Henry L. Snell

EVER since the period when the chipping hammer and file were the tools, and the blacksmith's forge and animal heat the heating apparatus, the evolution of methods for heating machine and other workshops has been in progress until it has reached the present stage. The first application of heat, without doubt, was the development of animal heat by hard manual labour with the hammer, chisel, file, and crowbar, that held the place now occupied by the lathe, planer, and crane.

This application ceased when demand and competition called for larger, less expensively produced and more accurate work, and the introduction of machine tools; but it possessed an advantage over modern methods inasmuch as it cost the proprietor apparently nothing, and distributed the units of heat with more or less "relative humidity" directly where wanted.

Possibly some objections from the workingmen of that day, of furnishing their own heat for the slight compensation which they were receiving for their labour, led to the next step in heating the machine shop, and the proprietor furnished the heat by digging a pit, or building a tub of brick or iron,—or more than one if the size of the shop demanded them,—and started an open fire of wood or charcoal upon it, letting the mixture of carbonic gas and smoke fill the shop while the workmen chipped and filed, alternately facing or backing to the fire in as close proximity as was safe, and possibly wearing overcoats and gloves when the temperature was zero outside.

The effect of this arrangement was to cause a column of heated air to rise to the top of the room and dissipate its heat, to a large extent, through the roof, and the heavy carbonic gas to fall to the ground (in those days floors were an exception), while a fresh supply of cold air came rushing in through every crack and cranny in the windows, doors, and outside walls, sweeping in direct lines along the ground and across the space occupied by the workmen towards the fire, and filling the partial vacuum caused by the ascending, heated air. Its capacity for furnishing heat to the occupant of the room was measured by the amount of radiant heat striking that part of his body that obstructed its rays It is not difficult to imagine under this condition of things a person roasting on the right hand and freezing on the left.

The next advance was in covering the fire with iron plates, either cylindrical or in box form, and calling it a stove, with a pipe for conveying away the smoke, gas, and some of the heat, thus furnishing an extended radiating surface and permitting some of the ascending column of air to become more highly heated and diffused through the lower portion of the room.

It is a well-known fact that heat rays in passing through pure air impart no heat to it, as they are absorbed only by coming in contact with the surfaces of solid bodies; but, in reality, as all air has more or less organic matter mingled with it, a slight increase of temperature is produced by passage of heated rays through it.

The action of the sun's heat upon the earth makes this statement self-evident; all know that the higher they ascend, or, in other words, the nearer they approach the sun, the less the temperature of the air, and it is accepted as a fact that the earth, by intercepting the heat rays, absorbs their heat, and, in turn, imparts some to our atmosphere by contact and radiation.

A knowledge of the above fact explains some of the advantages of the stove, with its conducting and radiating surface, over the open fire when used for heating purposes, but many of the objections to the open fire are applicable to the stove, while the danger from firing the building and the irregularity in the supply of heat remain with both.

All the above mentioned systems have been abandoned, except in small shops or for temporary purposes. After the introduction of the steam boiler a marked advance was made in methods of heating, and effectiveness of heating with economy and comfort became a consideration which led to the use of steam through pipes distributed about the shop, according to the ideas of the manager.

Some of the advantages of this system of heating over previous methods are a better distribution of the heat throughout the shop and around the walls, or colder parts of the building, and near the floor line; less intensity of radiant heat per square foot of surface, but with great increase of radiant surface; diminution of the danger from fire; removal of the deleterious effects from the escape of carbonic and other noxious gases; and additional useful space added to the floor surface in the centre of the shop.

Its disadvantages are, increase in cost of instalment; liability of damage from leakages or freezing; and its inflexibility, or its uniformity in furnishing about the same number of units of heat per minute, no matter what the outside temperature or intensity of external winds. This last disadvantage may be partially overcome by hand regulation of the steam supply, which introduces the elements of an individual personal equation, or by thermostatic control governing the irregular temperature of all parts of the shop by the regular temperature of some selected location, whereby results are produced not satisfactory to all the workmen, and the liability of the freezing of the water of condensation in some drip, valve, or exposed pipe is increased.

The design of heating by steam pipes is sometimes made by those who follow the practice of some stove-heating engineers, saying "if one stove is not enough we will supply another placed somewhere else," and they estimate the amount of heating surface required to heat a shop by the direct method, with steam or hot water, by rule of thumb, so that great variation exists in their practice. Their almost universal rule is to compute the cubic contents of the room to be heated and allow one square foot of heating surface to a certain number of cubic feet of space, varying from, say, 50 to 200, according to the judgment or practice of the designer. Reflection will readily show the fallacy of such assumptions, but failures in such cases have their remedy, for if one square foot of surface is not enough we can stick in another somewhere else.

Others, who mix intelligence with their experience, recognise the necessity of considering the losses of heat, first, by its transmission through the walls, ceilings, and glass surfaces; second, by the escape of heated air; and third, by the cooling effects produced by the entrance of colder air through cracks and open doors. They also give consideration to the construction of the building, its height, exposures, and the ratio of the external surface to the cubic contents.

Some intelligent rules have been given for estimating the amount of heating surface required for heating buildings varying in size or construction that take these losses into consideration, by A. R. Wolff, for example, in his treatise "On Heating Large Buildings," and by F. Schumann, in his "Treatise on Heat." Such rules rescue the problem from the realm of guesswork.

Having determined the amount of

radiating surface required, we have two methods of estimating the cost; first, the lazy man's method of allowing a certain sum per square foot of heating surface as the cost without boilers, and second, the true way, by making a plan of the layout and taking off the "quantities" and allowing for labour.

Machine shops, as at present constructed, are nearly uniform, except in size, and the requirements of one are generally those to be met in the other. They need ample and unobstructed floor space, high ceilings, so that travelling cranes may be used, abundance of glass surface in the outer walls for light and air, and uniform distribution of heat, of the desired temperature, throughout the whole internal space. The several methods thus far mentioned fail to meet this last requirement satisfactorily, and this fact has helped largely to bring the fan system of heating into favour.

As far as the writer has knowledge, the fan system was first applied in heating the works of the Boston Rubber Shoe Company, at Malden, Mass., near Boston, U. S. A. In 1873 the writer, while employed by one of the prominent blower manufacturers, was engaged in making a series of practical experiments with a view of determining some of the laws and coefficients of heat, and the capabilities of the hot blast system, then used only for drying purposes. The air, heated by the apparatus with which the experiments were made, was discharged directly into the main office, and was utilised for warming and ventilating.

One day Mr. E. S. Converse, president of the Boston Rubber Shoe Company, calling at the works and having his attention called to what we were doing, was impressed with the results he saw and felt, and suggested that the system be applied, in an experimental way, to two rooms at his factory, each 200 feet long, 60 feet wide, and 18 feet high.

This suggestion was carried out, and the results proved so successful as to justify the adoption of the system as the method of heating a new factory of the same size, but five stories in height, where specially designed apparatus was installed. From this beginning the use of this system has rapidly increased until at the present time it probably is safe to say that nine-tenths of all the large modern shops are using some application of it.

With this system a fan blower, or an exhausting fan, of suitable design, is located at any desirable place within or without the building. At the discharge outlet of the blower, or the inlet side of the exhauster, a proper amount of steam heating surface is placed, in the form of coils, cast-iron sections with vertical pipes of steel, or any of the various forms of cast-iron radiators, enclosed in steel-plate casings or brick chambers and connected with the fan. At the discharge outlet of the fan should be a main warm air duct from which will lead various branches, properly designed and located, with outlets for the most efficient distribution of the warm air. For supplying the heating coils live steam may be furnished from the boilers, or exhaust steam from the engines driving the works The power for driving the fan may be supplied by a steam-engine, electric motor, or belt transmission from main shafting.

The cost of installing a fan system is very often less than the instalment of a system of direct or indirect steam heating, or hot water heating, of equal effectiveness. The determining quantity in the cost is the amount of galvanised iron air distributing pipe, which is a varying quantity in shops of the same size and exposures, depending upon the existence and location of party walls or office rooms, and the location of the apparatus.

Among the principal reasons for this fact are that the more rapid circulation of air from a fan, as compared with natural circulation, enables the same number of units of heat to be imparted from a smaller amount of radiating surface; and that only from one third to one-fifth of the amount of pipe required with direct radiation will be necessary for the same results. Cases can be cited of the satisfactory heating of machine shops where one-eighth of the

amount of pipe that would be required by a direct system are in use with the fan system.

Again, the fan system utilises the exhaust steam without producing back pressure upon the pumps or engines, and gives results nearly equal to those from live steam. It distributes the heat into the lower strata of the shop and more uniformly over the entire space, instead of rising, as rarefied air always does, and wasting its heat units among the roof trusses or dissipating them rapidly through the roof covering. This statement can be verified by the senses if a ride be taken on a travelling crane where the fan system is used and repeated in a similar shop where the method applied is direct radiation.

By the fan system the operative is enclosed on all sides by a medium of warm air; by the direct system he is pelted by heat units with a fierceness dependent upon his proximity to the pipes. The fan design supplies pure and abundant fresh air without sensible draughts, and prevents incoming cold currents from outside; it presents facilities for moistening the air uniformly and to any degree of saturation, and produces a condition whereby a less sensible temperature of the room is more satisfactory and agreeable than with direct radiation. It also removes all delay in the operation of the shop from freezing of pipes and the damage attending therewith, and removes all liability from fire originating from the heating apparatus.

The fan may be located anywhere, but economy of first cost of installation will dictate placing it so that the distributing air ducts can be as cheaply arranged as possible, and the space occupied by it will possess little value for other shop purposes.

The flexibility of the system is a very desirable feature for either economy, comfort, or rapidity of action. By the turning of a valve, either by hand or thermostatic control, the speed of the fan and volume of air may be controlled, or by the admission of more or less steam to the heating coils the temperature of the air may be increased or diminished. There are no disadvantages in this system when properly designed and operated, but it should not be installed without a careful study of all the conditions, so that the right size of apparatus may be selected and a proper distribution of air made.

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CASSIER'S MAGAZINE

VOL. XXIII DECEMBER, 1902 No. 2

GOLD MINING IN EGYPT

By Charles J. Alford, F. G. S.

MR. ALFORD AT FATIRA

THE history of gold mining, indeed of all mining, in ancient Egypt is lost in antiquity. Vague rumours of ancient workings and of the ruins of mining towns in the eastern mountains have long been known, and some of the few travellers who have crossed the desert from the Nile to the Red Sea have mentioned them in a cursory manner; but nothing definite has been written or known about them until, in the winter of 1899-1900, an expedition was sent out under the superintendence of the author of this paper, by the Victoria Investment Corporation of London, with the express purpose of searching for, and reporting on, these ancient mines. The substance of this paper is, to a large extent, taken from the report on this expedition, with a description of subsequent explorations, bringing the subject up to date.

As an introduction, the following interesting communication from the pen of that celebrated Egyptologist, Professor the Rev. A. H. Sayce, M. A., may not be out of place, embodying, as it does, about all that is known of Egyptian gold mining in ancient days. Professor Sayce writes:—

"The eastern desert between the Nile and the Red Sea supplied ancient Egypt not only with stone, but also with vast quantities of gold. For several centuries Egypt was the California of the ancient civilised world of the East. The gold so largely used in Western Asia was derived from it, while at home the Pharaohs had at their disposal enormous stores of the precious metal. The foreign correspondence discovered a few years ago at Tel-el-Amama gives us some idea of what the annual output of gold must have been in the century before the Israelitish Exodus. The letters received by the Pharaoh from his royal correspondents in Asia are filled with requests for gold, which is described time after time as being as plentiful in his country 'as the dust.' If the King of Babylonia wants gold for a new temple he is building, it is to Egypt that he turns for it; if the King of Assyria corresponds with the Egyptian Court, it is to remind the Pharaoh that not only his father, but even the King of distant Cappodocia, had each received twenty talents of gold from the bounty of the Egyptian monarch, and that at least as much should be sent to himself. Egypt, it would seem, possessed sufficient gold to supply the whole world.

"Two centuries later, when Egypt

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ANCIENT RUINS IN WADY GAREYA BETWEEN KENEH AND FATIRA

had lost her empire, and had been overrun and devastated by barbarians from the north, the amount of gold yielded by the desert mines was still enormous. The great Harris Papyrus contains an account of the offerings and endowments lavished on the Egyptian temples by Rameses III., of the Twentieth Dynasty, and the royal revenue it implies is simply amazing. At a later date, under the Ptolemies, the gold obtained from the mines must still have been very considerable. The annual revenue of the second Ptolemy amounted to 14,800 talents, or more than four millions sterling; a large part of this was derived from the gold mines, and, according to Strabo, even under Ptolemy Auletes, in the closing days of the monarchy, when Egypt was in a state of financial and political decay, the royal income was still as much as 12,500 talents, or between three and four millions sterling. These high figures enable us to understand the statement in 1 Kings ix. 28, that the Red Sea Fleet of Solomon brought back in a single voyage from the emporium of Ophir 450 talents of gold, which, according to one calculation, would be equivalent to £3,240,000. The gold mines of the Egyptian desert must have been worked from a very early period. In a 'pre-historic' grave excavated by Mr. Quibell at El-Kab, at the end of the road which led from the Red Sea to the Nile, a small lump of gold weighing about an ounce was found buried with the corpse. On some of the oldest Egyptian tombs there are representations of the manufacture of gold ornaments and the jewellery of the Twelfth Dynasty (cir. B. C. 2500) discovered at Dahshur, and now in the Cairo Museum, is unsurpassed for the beauty and richness of its workmanship. A high official who lived at the time tells us in his biography that he had escorted the gold procured from the mines between Keneh and Kosseir, to Coptos.

"Fresh mines were constantly being opened in the Eastern Desert under the

Nineteenth Dynasty; for instance, we hear for the first time of mines in the Wadi Abbas, near Redisiya, and the mines of Akita,—now the Wadi Allagi,—were worked during the same period. A papyrus at Turin contains a map of the mines of Akita, and marks the position not only of the mines themselves, but also of the miners' houses, the well that supplied them with water, and the roads that led to the shafts. It would seem that the mines of Akita were first exploited by Seti I., who constructed a road to them from a point on the Nile in the Wadi Allagi continued to be worked under the Ptolemies, and a Greek writer, Agatharchides, who lived about B. C. 150, has left us a description of the way in which the quartz was crushed and the gold extracted from it. The process was somewhat rough, and it is not surprising, therefore, that a good deal of the gold obtained by means of it was anything but pure. Indeed, the inscriptions distinguish between gold ore, 'gold of the balance,' or marketable gold, 'best gold,' 'gold of the second quality,' and 'white gold.'

A WELL AT FATIRA

opposite the modern Dakka. He also sunk a well in the desert in the hope of finding water; but after boring through the rock to a depth of 120 cubits, or about 190 feet, he abandoned the task. It was, however, resumed by his son, Rameses II., who, after boring 12 feet deeper, succeeded in finding an abundant and perennial spring. The mines White gold was really electrum, of which considerable use was made.

"Besides gold, the Egyptians also mined for lead and silver. According to Diodorus, the inscriptions on the walls of the palace of Osymandyas or Rameses II. at Thebes, stated that the silver mines alone produced the prodigious amount of 3200 myriads of minae

THE MAIN SHAFT OF THE UM RUS MINE

in the age of the Nineteenth Dynasty (B. C. 1300); but white gold or electrum has probably been confounded by the Greek writer with silver, and in any case the amount must be exaggerated.

"It is clear, however, from the ancient evidence which we have been passing in review, that the eastern desert of Egypt is peculiarly rich in gold. Immense quantities of the precious metal have been taken from it in the past, and there is every reason to believe that equally large quantities are still to be found there. The mining methods of the old Egyptians were defective as compared with those of to-day, and it was only when the Egyptian Government was strong that the mining operations could be carried on at all. Whenever Egypt fell into a state of

feebleness and decay, or was overrun by a foreign enemy, the Bedouin at once became masters of the desert, the mining settlements were destroyed, and the roads to them rendered impassable. The wells sunk by the Pharaohs were filled up, and the traveller or miner had to depend on such rain-water as he could find in the hollows of the rocks. That a good supply of water can be obtained by boring is, however, certain, from the account which has been preserved to us of the well sunk by Rameses II., and it is equally certain that the ancient mines were deserted, not because the supply of gold was in any way exhausted, but because there was no longer a police to protect the miners and the roads along which the gold was carried to the Nile."

In these ancient days all mining was probably carried on by slave labour, and consequently at a cost with which we can never hope to compete; but though many small and poor deposits were then worked, there are evidences that in some of their mines they had ore which would be a credit to any gold mine. Their methods of working must have been of the most primitive description, and the suffering and loss of life amongst the workers very great. Agatharchides describes the methods of working thus:—

"The quartz was broken by fire and then crushed. The strongest men worked in the tunnels, breaking the rock out with iron hammers, whilst the old men and children carried the ore out to the crushers, where it was broken up by men and then further ground by women. It was then washed on sloping tables, the quartz being all washed away and the gold remaining behind. The gold was then melted in earthen pots, together with lead, salt, and a little tin and clay, and after five days' continuous burning the gold ran together, its quantity being a little decreased."

Mr. Futlerer writes in his work on mining in Africa:—"We do not know much of the Pre-Ptolemaic miners of Egypt, and must rest content with the fact that before the times of the oldest Egyptians, or in the earliest times contemporary with them, a mining people lived in the mountains between the Nile and the Red Sea who worked the gold mines. The Phœnicians had dealings with these people, and the Egyptians obtained a stream of gold from this source, the amount of which we can now have no idea of, unless by reading the descriptions of the treasures of the old Egyptian kings, or seeing the wonderfully finished ornaments in their tombs."

The ancient mining districts have been visited by very few persons in recent years, and those who have been there have given generally very meagre descriptions of the mines. Mr. E. A. Floyer visited some of the districts in 1887 and 1891, and his works and maps are valuable contributions to the subject; but his researches were topographical rather than geological. The geological survey of Egypt is also making progress in the northern districts.

Hundreds of European and American tourists, in pursuit of health or pleasure, now travel on the Nile, between Cairo and Assouan, every year; and, since the destruction of the Dervish power in the Soudan, Wady Halfa and Khartum have attracted many visitors. Thus the valley of the Nile has become as well known as any part of Europe; yet, within a few miles of the river, on either side, lies what is practically an unknown land. The sandy waste seen from the river, beyond the belt of cultivation, to the eastward, in no way represents the whole country between the Nile and the Red Sea. At Keneh, in lat. 26° N., the sandy zone, which forms the true desert, is but 20 miles wide, whilst in the latitude of Assouan it is fully 150. To the east of this, and bordering the coast of the Red Sea, is a chain of lofty and rugged mountains, 50 miles wide, several of whose peaks attain an altitude of 8000 feet above the sea, and the general altitude of the divide of the watersheds is from 1500 to 2000 feet. It is this belt of mountainous country that forms the mining district which we have to consider.

The most striking physical features of the country are the usually dry water-

courses, known as "wadies." These take their rise in the mountains, and run down on either side to the Red Sea or to the Nile. In its upper part a wady usually resembles an ordinary torrent-bed, but gradually develops into a long, flat, winding water-course, with cliffs of rocks on either hand, sometimes 200 feet in height, and a bed of sand and pebbles, in which all the lithological constituents of the neighbourhood are represented. At times, during the copious rains which fall in the mountains in the spring and autumn, these wadies are converted into rushing rivers, which carve out great holes in their beds and banks, and leave their marks on every side. Usually, however, they are only good, hard, sandy roads, with some small trees and plants, which form meagre but useful grazing for camels. Towards the Nile, on the west, and the Red Sea, on the east, the wadies gradually lose themselves in the sands of the lower districts, and probably little, if any, of the water which they bring down ever reaches the river or the sea on the surface. The crystalline rocks, which constitute the mountain districts to the east, are of the oldest geological series met with in Egypt. The larger mountain masses are usually formed of a hornblendic granite, with pink orthoclase, which gives the whole a strikingly red appearance when seen from a distance. Surrounding these, in the lower ranges, and covering very extensive areas, is a rather fine-grained grey granite, passing in places into gneiss, and that into mica schist, traversed by dykes and intrusions of greenstone, felsite, porphyry, and a very fine-grained white, elvan granite. It is in these rocks that most of the auriferous quartz veins were found to occur, and the more the granite was cut up by the intrusive rocks the more frequent and more promising the quartz veins appeared to be. In some districts masses of crystalline schists were found to occur.

Overlying the crystalline rocks, on either side of the mountains, is the very

WADY FATIRA

ACCESS TO THE GOLD-BEARING VEIN AT UM RUS IS GAINED THROUGH THE TUNNELS HERE SHOWN, AT VARIOUS LEVELS

large and geologically important formation known as the Nubian Sandstone, which appears to have been laid down on the eroded surface of the older rocks. This sandstone usually appears in well-defined strata of red, brown and grey quartzose rock, in many respects resembling the Old Red of Western England. Some parts are heavily charged with oxides of iron and manganese, and nodules of hard silicious hæmatite are of frequent occurrence. The whole mass, both sand grains and cementing material, is entirely silicious, with the exception of a few small local veins of sulphate of baryta and a little gypsum. Excepting only some fragments of silicified wood, found near the Wady Allowi, on the route westward from Assouan, no organic remains or fossils of any kind were found in these rocks.

The strata are usually horizontal or nearly so, but the general dip is towards the north in common with all the stratified rocks of the country. At the base of the sandstone beds occur local deposits of a rough quartzose conglomerate, with beds of variegated sands and sandy clays. Immediately overlying the crystalline rocks in several places are large lenticular deposits of a very hard, dark-coloured conglomerate, formed entirely of pebbles of these crystalline rocks, the pebbles varying in size up to large boulders. This beautiful rock is the ancient ornamental "Breccia" of the Romans, and was largely worked by them in the quarries of Hammamat, on the Keneh-Kosseir road, where a very extensive mass of it occurs. It is of much more frequent occurrence in the northern than in the southern districts, but the overlying Nubian sandstone attains an immense development towards the south, and it is impossible to say what it may cover.

Above the Nubian sandstone, and apparently unconformable to it, occur beds of cretaceous origin, which are best seen at the surface about the neigh-

A MINE HOUSE AT THE UM RUS WORKINGS

bourhood of Edfu and Rhodesia in the Nile valley, and extend to the north-eastward of Keneh, skirting the lower parts of the escarpments of the tertiary strata. It is in the lower beds of this series that deposits of coal or carbonaceous matter of some kind are reported to have been detected, but this most important matter requires verification. Above the sandstone are to be seen, first, a series of ferruginous sandy shales passing into black shales with carbonaceous matter and impressions of leaves, and it appears to be in further local developments of these beds that the coal deposits should be looked for. Above these are some calcareous sandstones with fragments of fossil wood, and beds of hard limestone with fossil mollusca, also local beds containing phosphates and fish remains. The cretaceous limestones occur at a short distance eastward of Keneh and Luxor, and also as an outlier on the crystalline rocks, eastward towards the Red Sea; but they do not appear to extend south of a line drawn in a north-easterly direction from Edfu to Kosseir.

The tertiary nummulitic limestone and other rocks overlying the cretaceous strata are not largely represented in the district under consideration, nor do they form a factor of any importance for the purposes of this paper.

The question of the water supply of these eastern regions of Egypt has always been looked upon as very serious, and the present scarceness as an almost insuperable obstacle to mining, or, indeed, any work in the country. To this I am not prepared to assent. Under present circumstances water is certainly scarce, especially in the lower districts on the sandstone strata; but in the eastern mountains there are few, if any, districts where a supply could not be got with a little work. The so-called "wells" of the Bedouin are nothing but holes grubbed with the hands in the sand of the wady beds; and as these stand for months untouched and unvisited, the water stagnates, and sometimes

THE COOK HOUSE AND SOME OF ITS ATTENDANTS

absorbs saline matter from the surrounding sands, and the holes become blocked with sand and *débris*. The "gults," or natural rock reservoirs, are no better, as most of them dry up shortly after rain has fallen, and others stagnate and become foul. The Bedouin has the greatest aversion to showing anyone the water-holes, and, whenever possible, says there are none, believing that nothing but the reputed want of water keeps all the nations of the earth from his beloved deserts, and, unfortunately, the presence of strangers has hitherto meant to him nothing but oppression and extortion.

All through the country, at the ancient mining sites and at all the old roadside stations, are abundant evidences of former water supply, in the form of cemented tanks, reservoirs and catchment arrangements, and many well-made masonry wells, all now completely choked with sand,—indeed, many bear traces of intentional destruction. The first work towards reopening the mines must be to put some of these in order and provide an adequate water supply, and it will not be difficult or very expensive. The want of timber and fuel in the country is more serious than the present scarcity of water; but as both of these will have to be supplied from the outside, the question really resolves itself into one of transport. In the absence of cheap coal, petroleum will probably commend itself as a fuel for small engines.

The cost of English coal at Luxor on the Nile is now thirty-five shillings per ton, and it could probably be put down at the Fatira Mines at forty-five shillings. Camel carriage of any material will cost about one penny per mile per load of 300 to 400 pounds, and camels are readily obtainable. The mines on the coast would have a great advantage in being supplied by sea from Suez, which is not more than forty-eight hours steamer run from any port on the coast of the district. A railway has been projected and surveyed between Keneh and

A DAM HAS BEEN BUILT ACROSS ONE OF THE SMALLER WADIES, SO AS TO AFFORD A WATER SUPPLY FOR THE MINE AT UM RUS

Kosseir, which would pass close to some of the mines, but the scheme is at present in abeyance. These questions apply rather to the future than to the present, as the first exploration and development of the mines will require no machinery and very little timber, and the carriage of the necessary stores and tools will not be a serious matter.

The eastern desert is inhabited in the south by two tribes of Bedouin Arabs, the Bisharin and the Ababdeh, who are said to number in all about 80,000 persons, and occupy the country from Suakin northwards to the Keneh-Kosseir road. These two tribes are under the nominal rule of Beshir Bey Gabron, a very intelligent and friendly old man, who supplied the camels for the expedition on the southern journey; his headquarters are at Assouan and Rhodesia. North of the Keneh-Kosseir road the country is occupied by the Maaza and Bili tribes of Bedouin, who number about 9000 persons. These northern tribes, from their more frequent intercourse with civilisation, have become more tractable, and are easier to deal with than their brethren of the southern districts. The Bedouins, as a rule, are a truculent and unruly people, very poor, shiftless, and improvident, living a wandering life in the desert, where their only occupation is the breeding of camels and a few miserable sheep, and the manufacture of a little charcoal. Their tents are only a few sheepskins, or an old sack or two, stretched over some sticks, and in these the women and children are kept, whilst the men live constantly in the open. Thus they wander about in families, who often fight with one another over the scanty grazing grounds of the desert. The Bedouins have the greatest aversion to any kind of manual work, and the only kind of useful occupation to which they will apply themselves at all is that of

camel drivers and carriers; unfortunately, the extinction of the Soudan trade, by the troubles of late years, and the turning of trade from Kosseir to Suez, has gone far to deprive them even of this means of earning a living honestly.

The Fellahin, or working men of the Nile valley, are a very different class from the Bedouins. Generally they are industrious, hard-working, and civil, comparing favourably with any European labourers; but they can hardly be called intelligent, and have little or no initiative power. Whatever work a fellah is set to do, he will go on doing until he is told to stop, without thinking if the work be usefully done or not, and long ages of hereditary serfdom have given them the cringing meanness of mendicity, which is not a pleasant trait. They are, however, when properly superintended, excellent labourers; their wages are from four to eight piastres = 10d. to 1s. 8d. per day. Skilled miners would have to be brought from Europe, and for these I should strongly recommend Italians, who are much more suitable to the country in every respect than British workmen. Native blacksmiths and carpenters of fair ability can be got in the country at wages varying from ten to fifteen piastres = 2s. to 3s. per day. In the initiatory prospecting work these wages have generally to be supplemented by rations of flour and lentils.

The climate of Egypt generally, and of the eastern desert in particular, is one of the finest in the world, the only drawback being the excessive heat of the summer months; but at all times the air is dry, and malarial diseases are unknown. During the winter months the cool, bracing air of the desert, with the constant sunshine, form a climate which cannot be surpassed. In October, November, February and March the eastern mountains are sometimes visited by violent rainstorms, which turn the wadies into torrents for a short time, but do not extend far into the desert to the south-east, where rain is almost unknown. After the rains, vegetation springs up rapidly in the wadies, and as rapidly dies off before the burning summer sun.

Animal life in the eastern desert is very scarce. Of insects there are a few ants, and some interesting beetles, whilst the ubiquitous Egyptian fly is by no means so common as in other parts of the country. The only creatures which may be called dangerous are a few small vipers, and some scorpions, and stinging spiders, generally found amongst the rock fragments in the wadies. Game is represented by the ibex, or mountain sheep, and a small species of gazelle, which are occasionally met with amongst the mountains, but do not appear to be plentiful anywhere. Generally life is scarce in the desert.

At present, whilst the water supply is so small, and there is consequently no food for horses, mules, or oxen, the only means of travelling across the desert is by camels, which can be readily hired from the Bedouins at a week or two of notice. The hire of a camel, including food and attendance, is about 12 to 20 piastres (2s. 6d. to 4s.) per day, according to circumstances, and the attendants should certainly not be less than one man to every two camels. A camel can carry a load of about 400 pounds at the rate of twenty miles per day for eight or nine consecutive days, after which a few days' rest is necessary. It requires water about every five days, but can go without for double that time at a pinch. Few of the desert camels care to drink at less intervals than four days. For food, the drivers give them once or twice a day a handful of hard beans or durra, and they pick up some scanty grazing in the wadies; but, generally, the Bedouins take too little care to provide them with sufficient food, and there is always danger of a breakdown unless this is carefully looked after. When a camel once begins to give way it goes very quickly, and takes a long time to recover. For a party of Europeans, carrying water, provisions, and tents, six camels per traveller is none too large a provision.

The difficulties in crossing the desert are entirely owing to the present inadequate water supply. In ancient times

camels were unknown, and there is evidence that traffic was carried on with oxen, mules, or horses. There is no reason why these should not be again employed in many districts where a water supply could be obtained, and with it some cultivation of the necessary food for draught animals. In most parts the sand and pebbles of the wady beds form convenient roads for wheeled vehicles, or could be made into such with a little clearing.

The foregoing description of the country between the Nile and the Red Sea, between latitudes 23° and 27° N., results from the report on the country made by the writer on behalf of the Victoria Investment Corporation, having for its object the locating of some of the long-lost ancient mining sites, in view of subsequent exploration. A number of these were discovered in the mountainous districts formed by the crystalline rocks which have been described, and were found to be generally much of the same character, but varying greatly in size. In all cases they are somewhat irregular groupings of small huts, sometimes circular and sometimes square or oblong in shape, built of rough, unhewn stones. The walls are usually single; but, in some cases, as at Um Rus, there are ruins of huts built with double walls, the interstices being filled in with small pebbles and rubble. The huts vary much in size, but appear to have been very generally from 50 to 100 square feet in area. At times they are grouped together and form a considerable town, with an outside wall, large enough to accommodate a thousand men or more; in other cases the huts lie scattered in groups of two or three along the sides of the wady near the mine workings.

In several places, as at Fatira (see page 276), long lines of stones appear to represent walls between which prisoners may have been confined, and the ruins of what have probably been watch towers at either end point to the same conclusion.

Nothing now remains of any of these but the fallen stones of the walls marking out the ground plan, and in many cases this is much obscured by a covering of drift sand. The ancient mine workings were, in all cases, found to have been from the outcrops of the veins, and to have followed the oreshoots downwards in an irregular manner. In no case did we find that any attempt had been made to get at the vein by means of a cross-cut tunnel from the wady below, although the configuration of the ground lends itself admirably in many cases to this method of working.

Everywhere the old workings were found filled and choked with sand, so that the ancient working faces and bottoms could never be reached; consequently no remains of ancient mining tools were found. The only vestiges of the early mining appliances to be seen were the old quartz mills and rubbing stones, of which many specimens, in various states of preservation, remain amongst the ruins. Of these there appear to have been two classes,—one an elliptical rubbing stone, on which the quartz was probably reduced to a coarse powder by attrition with a stone rolling pin, and another, in the form of a mill, with an upper and lower grinding stone. The quartz was probably first broken and coarsely pulverised upon the elliptical stone, and afterwards reduced to a fine powder in the circular mill, and the gold then extracted by washing, as already described. It is probable that a further exploration amongst the ruins and in the old mine workings may result in the discovery of interesting relics of the ancient workers, which the great distance this expedition had to cover in a limited time precluded searching for.

During the last twelve months the work of exploring the country and the ancient mines has been pushed on energetically by the Egyptian Mines Exploration Company in the district above described, whilst the Egyptian Development Syndicate, the Egypt and Soudan Mining Syndicate, and some others have also commenced exploration work on large prospecting areas granted to them for a time by the Egyptian Government, with the right to locate and hold, on certain specified terms, any mines found therein, a system admirably adapted to the country, in which the

presence of the independent strolling prospector would be particularly undesirable.

At Um Rus, on the western coast of the Red Sea, about 240 miles south of Suez, the exploration of one of the ancient gold mines was commenced in December, 1900, by the Egyptian Mines Exploration Company, under the superintendence of the author of this paper, and so far the results have been decidedly encouraging. The mine is about four miles from the Red Sea, where there is a good natural harbour named Imbarak, in which any moderate-sized vessel can anchor and lie in perfect safety. At this point, over an area of about three square miles, occur a large number of quartz veins outcropping in a country of grey granite much intersected by dykes of greenstone, porphyry, and felsite. Nearly all of these veins have been more or less worked in ancient times, and some of them to very considerable depths.

In the Wady Imbarak, south of the mine, are the ruins of a large ancient mining settlement, and remains of huts are scattered all over the neighbourhood. The country is very rough and mountainous, and intersected by numerous wadies, which, when the heavy rain storms break in the mountains, bring down large volumes of water. Across one of the smaller wadies a dam has been constructed to conserve a supply of water for the mine, capable, in its present state, of holding 500,000 gallons, and of enlargement to almost any size. An illustration of this appears on page 284.

The exploration work was commenced on one of the largest of the ancient workings where two veins of quartz outcrop in the cliff on the north side of a wady. These had been both very extensively worked by the ancients, who appear to have had a clear idea of the nature of ore-shoots, as they worked certain zones of the veins entirely out,—in one case a length of 700 feet,—leaving hardly a trace of quartz in their old stopes, whilst other and less rich portions of the veins were left untouched. It is noticeable that whenever a piece of quartz can be found in any of these old stopes it generally shows a good result in gold, whilst the untouched portions of the veins are generally poor. In view of this the scheme of exploration is to get below the level of the old workings, and then to drive underneath them and thus to get into the ore-shoots worked by the ancients.

A good working shaft, which is fitted with winding engine and track, has been sunk in the granite country rock below the lower vein, thus avoiding the broken ground of the ancient workings. This shaft is now down over 200 feet and about 30 feet under the vein. A cross-cut was made to the vein at the 170-foot level which showed that at that depth it was still in old workings; but a large piece of the vein, left intact by the ancient workers, showed 40 inches in thickness of quartz, which assayed in places 10 dwts. of gold per ton. It is proposed to cut the vein again at the 230-foot level, which, it is hoped, may be found to be below the old workings. A tunnel is also being driven on the lower vein which, at 210 feet, has 24 inches of quartz in the face, assaying nearly 7 dwts. per ton of gold.

The upper vein has been opened by a cross-cut, 140 feet long, and is now being driven upon to northeast and southwest. In the southwest face there are 11 inches of quartz, assaying nearly 5 ounces of gold per ton, and in the northeast face there are 18 inches showing a little gold. From the old workings on the outcrop of this vein samples have been taken assaying up to 10 ounces of gold per ton; but these rich assays generally come from small pillars, or pieces of quartz, left by the ancients in their workings.

The Fatira Mine, about forty-five miles northeast of Kena, has had a good deal of work done on it during the past year. An immense quantity of rubbish has been removed from the ancient workings on the outcrop of the veins, and more than a hundred openings have been made into them. Definite exploration work has been commenced at four points, and in the aggregate over 200 feet of tunnel driving has been

A TUNNEL ENTRANCE AT THE UM RUS MINE

done on a rather flat vein of brecciated quartz, 20 to 50 inches thick, and assaying in places up to 3 ounces of gold per ton. Altogether, the prospects, both at Um Rus and Fatira, appear to be promising.

Experience has shown that the natives take very readily to the mining work, and when treated judiciously, with no violence, are tractable and willing. It has been found best, as far as possible, to do away with the old system of the country under which labourers were engaged in gangs from the village sheik, and paid through him with large deductions, and to take on the men at the mine as they come and pay each individual man his own wages. The men like it best, naturally, and though many work but a few weeks at a time and then go back to their families, they soon return to work and are more useful each time.

There has been, so far, no lack of water; indeed, at times there has been far too much of it, and by constructing dams to retain the rainfall, reopening old wells and sinking new ones in suitable places in the wadies, a supply can almost always be obtained. In places, however, the well and mine water is distinctly brackish, but never appears to contain anything more deleterious than a trace of salt and sometimes of sulphate of soda.

Perhaps the most serious question in connection with Egyptian mining at present is the cost of fuel. A very fair charcoal is made in the country by the Arabs, but the supply is limited. English coal at Suez costs 45s. per ton, and on the Nile at Keneh 35s. It is possible that if a large demand were created Indian coal could be put down at Red Sea ports at less prices than these, or the use of petroleum might be cheaper; but as the high price of European coal at Suez is largely caused by the heavy canal dues, all fuel coming from that direction would be equally affected.

In addition to gold several other valuable mineral products have been discovered in these eastern districts of Egypt. At Jebel Jassus, about two miles south of Safaga Bay, on the Red Sea, are some ancient mine workings in a steep hill of crystalline limestone. The strata of limestone are sharply tilted up from the east and the adjacent country is generally disturbed, with large accumulations of pebble drift in the valleys and masses of sand towards the sea. The whole side of this hill is covered with old workings. These appear to have penetrated to a bed of indurated limestone, which occurs a few feet below the surface, and which carries impregnations of galena. Almost every trace of this ore has been removed by the old workers, so it is difficult now to ascertain what this bed ever contained. A sample of galena was, however, collected by chipping small pieces from the limestone wherever any of the ore could be seen, and this, roughly concentrated, gave an assay of lead, 50 per cent.; gold, 2 dwt.; and silver, 3 oz. per ton. The Bay of Safaga, at the foot of the wady, is said to be an excellent harbour; but it is not now made use of, and there are no inhabitants or buildings in the neighbourhood. A route from here leads down the coast, about forty miles, to Kosseir, a somewhat important harbour, from which a native trade is carried on in corn and other commodities with the Arabian coast of the Red Sea.

About ninety miles W.S.W. from Luxor, and fifty miles from the Red Sea coast, near the ruins of the ancient settlement of Abu Geraia, are some extensive and most interesting ancient marble quarries, one mile north of Wady Mia. Here an outlier of limestone on the granite has been converted into a beautiful white statuary marble, resembling that of Carrara, by the intrusion of dykes of felsite and greenstone,—the

A MINING CAMP AT FATIRA

THE EGYPTIAN MINES EXPLORATION COMPANY'S STEAMER "PROSPECTOR"

latter penetrating the marble mass and the former adjacent to, and in contact with it, on the west side. Enormous heaps of chippings show that the marble had at one time been extensively worked; but, with the exception of one fragment of a broken vase, we could find no worked pieces. The neighbouring country is generally talc schist and grey granite, and the occurrence of this marble mass at so great a distance from any rock of its kind is an interesting geological problem. For years Egyptologists have been puzzled by the existence in many ancient buildings throughout Egypt of a white crystalline marble of great purity and beauty, the original source of which was quite unknown. Many ancient monuments were therefore, perforce, left unrepaired by the committee for the preservation of Arab monuments, as the use of European marble beside the ancient portions would have destroyed the symmetry of the effect. Here at last the long-sought marble was found, and the matter has been warmly taken up by the architect of the committee. Unfortunately, the distance of the quarries from the Nile renders the cost of transport, which at present has to be done entirely by camels, so high that in spite of its superior quality this marble has little chance of competing in the market with that from Europe.

In the winter of 1899-1900 an expedition was sent out by Messrs. Streeter & Co. to explore the ancient emerald mines of Jebel Zabara, about eighty miles south of Um Rus and twenty-five from the excellent little harbour of Sherm Sheik on the Red Sea coast, and encouraging results were obtained. It is to be regretted that these explorations have not been continued, as it is certain that in ancient days these Zabara mines produced emeralds of the finest quality and in large quantities. The emeralds are found associated with great quantities of beryl in a matrix of mica schist, a large zone of which appears from under the Nubian sandstone

to the westward of Jebel Nikhari, south of the Hamesh gold mines, and from there extends eastward to Jebel Zabara and the sea. There is also another zone of micaceous and talcose rocks, in which emeralds might possibly be found, to the north of Eridia, eastward of Keneh.

Turquoise is being worked by the Egyptian Development Syndicate in the peninsula of Sinai. It usually occurs lining cavities and fissures in the Nubian sandstone, and varies greatly in value according to colour and hardness. Some small specimens were found by the writer in the neighbourhood of Eridia.

Deposits of phosphate of lime occur, associated with limestones of Cretaceous age, to the eastward of Keneh, on the right bank of the Nile, also there are some large deposits of the same on the coast of the Red Sea about Kosseir which have been found to extend parallel to the coast for sixty or seventy miles. These have been to some extent sampled and reported on by Mr. Frank Western, A. R. S. M., and show results quite warranting an exhaustive and systematic exploration, which is now being commenced.

The exposure of the crystalline rocks in which the ancient gold mines of Egypt were worked, and in which search for deposits of metalliferous minerals may be undertaken with prospects of success, commences about Jebel Zeit, at the south end of the Gulf of Suez, and extends, in varying width, along the coast line of the Red Sea, with few and slight interruptions for 700 miles, until it joins the mountains of Abyssinia. At Um Rus the mountain chain of crystalline rocks is about 60 miles in width from east to west, whilst 100 miles south it decreases to about 30 miles; then, in latitude 22° N., the boundary line between Egypt and the Soudan, it extends from the coast westward for fully 200 miles, and, with occasional covers of sand, all the way to the Nile.

The country to be explored is very great, but it has many advantages compared with its difficulties, one of the greatest of these being the unvariable healthiness of its climate; and it only remains to push on the work, now well begun, in the hope of establishing again, after these long ages, the mining industry of this most ancient and interesting country.

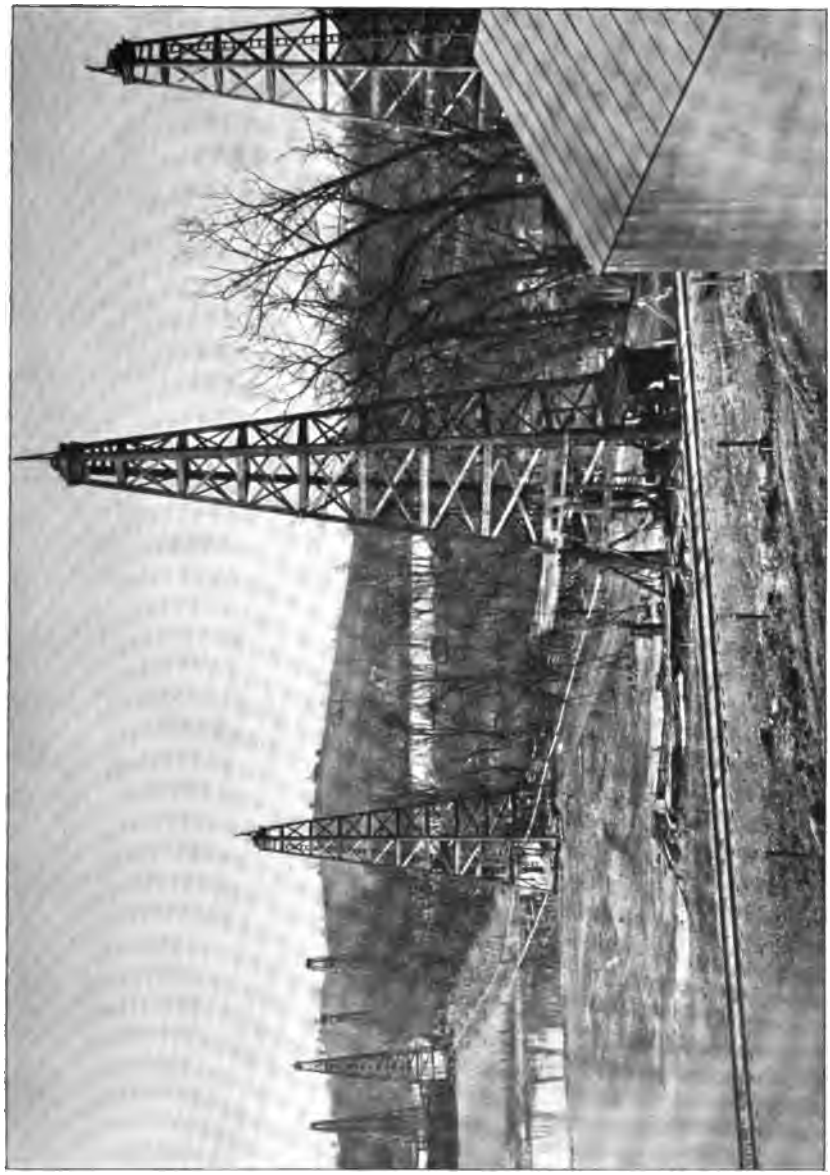
HAULING OIL TO THE RAILWAY

AMERICAN PETROLEUM POSSIBILITIES

By George Ethelbert Walsh

THE early history of the American petroleum industry furnished many illustrations of the successful conversion of natural resources into profitable commercial articles through the genius and efforts of pioneer captains of industry; but startling as some of these early exploitations of mineral wealth were, it is doubtful if they ever eclipsed those which have been made public within the past year. American petroleum is apparently entering upon a new era which justifies predictions of possibilities likely to be realized within the present decade. Oil as a fuel for manufacturing purposes has proved its worth and importance on the Pacific coast, and the promises of its entering the field in direct competition with coal in the East are sufficient to induce many manufacturers to equip their plants with furnaces adapted to its use. The establishment of a line of oil tank steamers between New York and the nearest port to the new Texas oil fields comes partly as the direct result of the recent American coal strike, but more specifically as the natural outcome of conditions which have gradually been shaping themselves toward this end for

PUTTING DOWN SIX-INCH PIPE IN ONE OF THE WELLS OF THE KING-CROWTHER CORPORATION IN SOUTHERN TEXAS



IN THE HENDERSON OIL FIELD, IN WEST VIRGINIA, OF THE OHIO & CALIFORNIA REFINING OIL COMPANY

OIL TANKS IN THE KERN RIVER DISTRICT, CALIFORNIA

the past ten years. Americans have been slower than most of the European countries in adopting oil as a fuel because of the great abundance of wood and coal in nearly all parts of the United States; but the advantages accruing from the use of oil are gradually being appreciated by a larger number of manufacturers every year. The European pioneer workers in this field have furnished abundant experiment with different types of oil-burning apparatus, so that in adopting this fuel there has been less trouble than if American inventors had for the first time attacked the problem. On the Pacific coast oil-burning plants have multiplied in the past two years to such an extent that almost the full output of the oil fields of that region is consumed right at home.

As a permanent factor in the fuel question of the day, however, oil must depend entirely upon the possible supply held in the earth for future use. As to the permanency of this supply, scientists differ, and possibly this difference of expert opinion has been partly responsible for the slowness of manufacturers in changing their furnaces to meet the needs of the new fuel. Nothing would be more disastrous to the manufacturing industries than to have the oil supply suddenly decline so that increased cost would prohibit its general use as a fuel. Consequently, until greater assurances of the permanence of the oil supply are obtained, manufacturing plants will continue to burn coal while installing auxiliary oil burners. The recent strike in the anthracite coal regions unsettled business to such an extent that large consumers of coal prepared for another such emergency by having auxiliary oil-burning furnaces installed. This new movement may extend indefinitely, as the price of oil continues low and the supply shows no signs of abatement.

But in view of the question of permanent supply it is interesting to note some of the remarkable changes in oil mining that have taken place in the past two or three years. We have had an oil "boom" of unprecedented size in the past two years, and while the inflation of the bubble may be carried to a disastrous extent by speculators, manufacturers are content with only exact figures of production and their relative bearing on the future of the supply. In the past year the petroleum industry of the United States reached the high-water mark of its whole history, and unless eclipsed by the present year's business it will probably stand as the record year for some time.

It should be noted that while remarkable fields of oil were discovered and opened in Texas and California the supply of oil in some of the older fields decreased. In fact, throughout all the great Eastern or Appalachian petroleum field the decrease was marked, and when we realise that fully 80 per cent. of all the petroleum obtained in the United States for 1901 came from this and the Indiana region, its importance cannot be underestimated. Time and again the old oil fields of Pennsylvania have been abandoned through their complete exhaustion or the difficulty and expense of pumping up the oil from the very low regions. The decrease in the older Appalachian region, however, was partly offset by a slight increase in the so-called Lima-Indiana region.

This decrease is attributed to the abandonment of the old wells and to the failure to open new ones, and not altogether to the exhaustion of the supply of oil. So long as oil is plentiful it will be mined in the regions where it can be obtained at the least expense.

The discovery of oil in Texas suddenly cheapened the product so that only the very productive wells in the older regions were operated. Under ordinary circumstances many of the abandoned wells in the Appalachian region would have been used, and new ones would have been opened and operated, so that the decrease in the supply would not have taken place.

In estimating the amount of oil in the earth the future possibilities of the old Appalachian region must be considered. In spite of all the advertising of the Texas and California oil regions, they produced, along with all the other minor regions outside of the Appalachian and Lima-Indiana fields, only about 20 per

A PUMPING STATION AND STORAGE TANK OF THE STANDARD OIL COMPANY AT BOAZ, WEST VIRGINIA

cent. of the product mined in 1901. This amount was also only about 12 per cent. greater than that supplied by the same fields in 1900. However, the industry represents such an enormous increase in capitalisation and work that the increase in the supply from these regions will probably become more important in the next five years.

During the past year, according to figures furnished by the United States Geological Survey, 1578 oil stock companies were organised, with the huge capitalisation of $669,083,000. The investment of this vast amount of capital in oil companies does not, however, indicate that it has all been wisely spent in constructing machinery and developing the output of the oil fields. A good part of this capital may be diverted from its legitimate purpose, and much of it has probably already been wasted through ignorant methods of mining and experiment. Then, too, there are possibilities of swindling operations which may be conducted on a huge scale until the bubble bursts. Consequently, in the present excitement over the industry neither the number of stock companies in the field nor their actual capitalisation proves anything. There is little in them as an aggregate upon which to base calculations for future production. One is forced back upon statistics of actual increase in production throughout the country and the relative output of the different oil regions of the country.

From the same source it is found that about 14,250 petroleum wells were completed in 1901, while a great number were begun in search of oil but were abandoned before completion. Even of those completed 3220 proved unproductive and are classed as abandoned or dry. The loss of invested capital on these is enormous, for on the total 14,250 there were expended $21,375,000, or approximately $1500 on each one. The 3000 odd dry wells thus make a total loss of nearly $5,000,000. The millions lost in the numerous attempts

to bore for oil which were abandoned before the wells were completed represent a much larger capital than that wasted in wells which proved dry after they had been finished. A good many of the oil stock companies were recklessly formed and as recklessly managed in the field of actual work. Some showing had to be made in the oil region, and derricks were erected and a shift made to bore wells; but in a great many instances there was no possibility or probability of striking oil. The stock companies were organised and managed in the interests of the promoters. No form of guarantee was given that oil would be reached, and the profits were left entirely for the future to determine. While some of the stock companies owned land that was valuable, and the funds subscribed by the public were legitimately placed in the enterprise, dense ignorance in developing the properties in many instances almost neutralised the natural advantages possessed. Of course, there were stock companies which were not inflated, and which were operated successfully and intelligently, reaping great financial rewards for the promoters and subscribers.

The production of petroleum in the United States in 1901 reached the enormous total of 69,380,194 barrels, representing an increase of nearly 10 per cent. over the production of the previous year, or 11 per cent. over 1899. In fact, for the past five years the gain has averaged from 5 to 7 per cent. over each previous year. It is estimated that the increase for the year just passed over 1901 will probably amount to from 15 to 20 per cent., owing to the fact that thousands of the large wells projected and completed last year have just begun to yield their product. Moreover, more wells were started in the latter part of 1901 than were actually finished in the whole year; this will naturally bring the total number for the year 1902 much higher than for 1901.

While the total production of 1901 was the largest on record, the valuation of the oil obtained was considerably less than for 1900. This was due to the sharp decline in oil on account of the enormous production of the Texas and California oil regions. The 1901 production of 69,389,194 barrels of oil sold on an average at 95.7 cents per barrel, or for $66,417,335, while the oil of 1900 sold on an average at $1.194 per barrel, making the total production of 63,620,529 barrels for that year amount in valuation to $75,989,313. This decline in value of $9,571,978 forms an important consideration in the estimates of the oil product. But instead of discouraging

A GUSHER AT PORT ARTHUR, TEXAS

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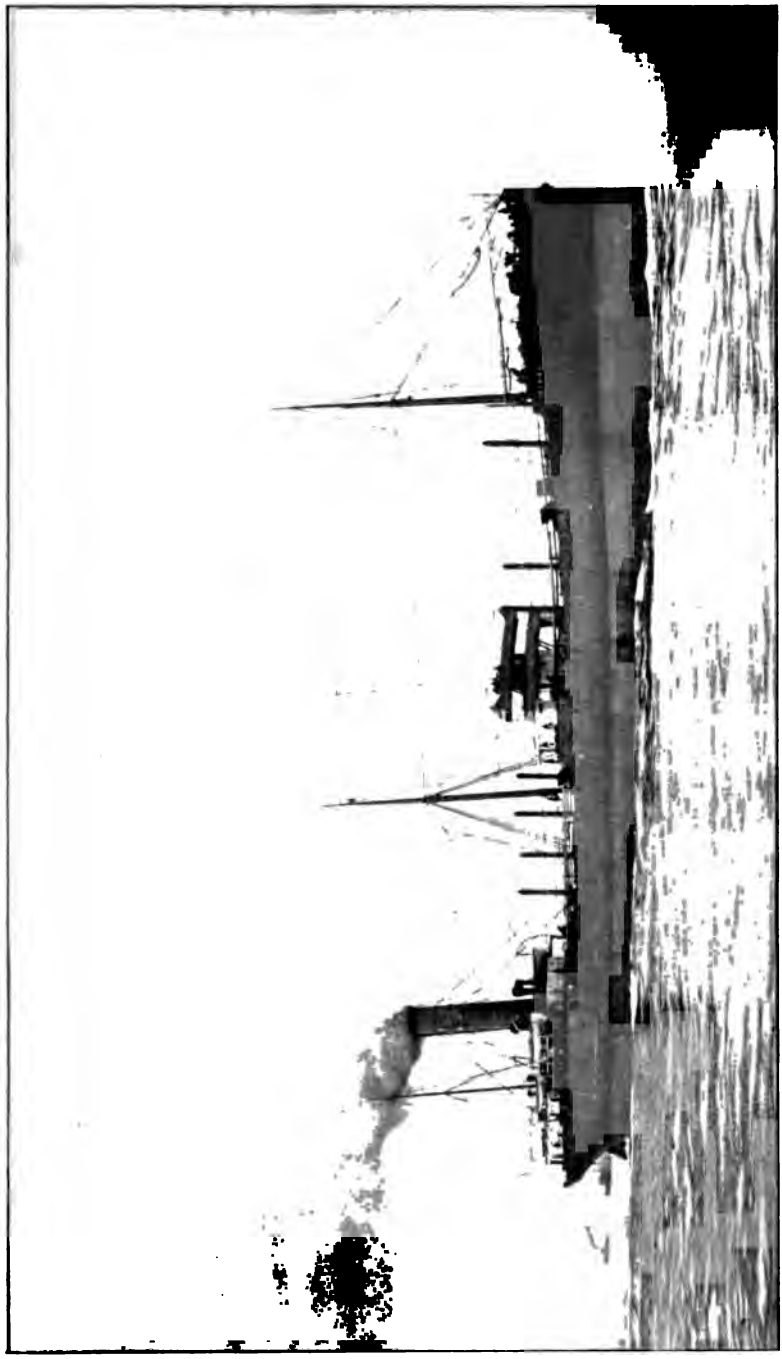
A GROUP OF OIL WELLS IN THE SUNSET DISTRICT, CALIFORNIA

AN OIL SPRING IN TEXAS

oil mining, it has tended to stimulate it. The decline in price has brought the oil within the reach of manufacturers desirous of experimenting with it for fuel purposes. Oil as a fuel must sell below a dollar a barrel to enter into competition with coal, and as soon as the production diminishes so that the price goes above a dollar, manufacturers will cease to use it on a large scale.

The value of the petroleum, however, differs in various parts of the country fully as much as the amount of production does. The Pennsylvania product brought the highest price in the market, and the Texas the lowest. In the latter State the decline in price was 75 cents a barrel, and in California the decline amounted to over 37 cents a barrel. This was due entirely to the great abundance of the oil and not to an inferior quality. The Pennsylvania and Ohio product was nearer the great markets, and the decline was only 14.6 cents a barrel to make up the difference in the cost of transportation. Pennsylvania was the third State in the Union in respect to total production, with 12,000,000 barrels to its credit, while Ohio produced about 21,000,000 barrels, and



THE OIL TANK STEAMER "PINNA." BUILT FOR THE AMERICAN PETROLEUM EXPORT TRADE BY SIR WM. G. ARMSTRONG, WHITWORTH & CO., LTD., NEWCASTLE-ON-TYNE, ENGLAND

West Virginia 14,000,000. California followed Pennsylvania with about 8,000,000 barrels, Indiana came next with 5,000,000, and Texas followed with 4,000,000.

To divide the oil production up according to regions, and not by States, it will be found that the old Appalachian fields produced for the year 36,600,000 barrels; the Lima-Indiana regions 21,900,000; California a little over 8,000,000, and Texas a little over 4,000,000 barrels. The total quantity of oil added to the country's production by the two new regions would not thus cut such a remarkable figure as some have been led to suppose. With a total output of something like 13,000,000 barrels, Texas and California have succeeded in bringing down the price within the means of manufacturers anxious to use oil for fuel, but they have not by any means eclipsed the great original fields which, for upward of half a century, have been mined successfully for this mineral product.

The question which naturally concerns the whole country in the near future is whether the new oil regions will continue to yield as steady a flow as the Appalachian and Lima-Indiana regions yielded for the past decade or two. If these new fields show such superabundant supplies of oil as the older regions, the use of petroleum for fuel will become a permanent factor in American manufacturing industries in the next twenty-five years. It will be almost revolutionary in its results upon the fuel problem.

The export of American petroleum has in recent years grown to mammoth proportions, and it was considered possible to find sufficient foreign markets for the surplus to keep the price of oil up to old figures; but the sudden development of the Texas and California fields immediately depressed prices. For the first time in the history of the industry the total exports exceeded last year a billion gallons. According to the official figures, the total exports reached in 1901 the huge number of 1,062,750,306 gallons, a gain of almost 10 per cent. over the exports of the previous year. But the total value of these exports, owing to the lowering of

OIL FLOWING FROM A WELL TO A STORAGE TANK

the prices, was less than in 1900. The average price received for the exported oil was 6.73 cents a gallon for 1901 and 7.52 cents for 1900. This made the total valuation of the exports for last year $71,479,124, and for the previous year, $73,276,282. Compared with the exports of oil from other countries, the United States stands pre-eminently first. Russia's exports of petroleum in its different forms last year were only about 36 per cent. of the amount exported from the United States, or a total of 390,920,095 gallons.

It is not likely that the American exports of petroleum will increase much above these figures in view of the present development of the industries using oil for fuel. With prices lower than a dollar a barrel, petroleum becomes a useful fuel in many lines of industries, and it will pay to utilise the oil for manufacturing purposes rather than to export it. In nearly all the countries to which the American manufactured petroleum is exported there are prohibitive duties upon it. Great Britain alone has no high duty on the product. The question of using the oil product for fuel in the manufacturing industries of the United States consequently is to-day one of the most interesting problems which manufacturers of machinery and other articles are considering. While there is no danger of a coal famine or material increase in the permanent price of coal, it is a fact, demonstrated in the current year, that strikes, either in the coal mines or on the railways, may at almost any time precipitate a condition which will make the use of coal an expensive and difficult matter. To avoid another such emergency a great many plants are equipping themselves with oil-burning furnaces, not so much for the purpose of discarding coal as a fuel as to be furnished with an auxiliary or emergency power. In some lines of manufacturing it is even possible that oil will be used exclusively in preference to coal. This certainly will be the case so long as oil remains as low in price as at present and coal sells at current rates. The change, partial though it may be, will eventually produce effects of considerable importance and of far-reaching consequence in the American industrial world.

A TANK TRAIN GOING TO TIDE WATER

THE MECHANICAL INVENTORS OF LANCASHIRE, ENGLAND

THEIR INFLUENCE ON SOME BRITISH AND FOREIGN INDUSTRIES

By Sir W. H. Bailey

IT is profitable for commercial men at all times to study industrial history, the fluctuations of industrial geography, and the causes that have led to the foundation of the great industries of manufacturing districts.

With this thought in mind, the writer undertook, a short time ago, to collect and present in an address before the Manchester Library and Philosophical Society, the names of men of mechanical genius of the great British industrial community of Lancashire,—men who have assisted in notable degree in founding British industry, and the outcome was substantially what is given in the following pages.

Industrial history enables us to measure and assess our position in relation to that of our competitors abroad. The causes that have given us command of markets may operate against us if we ignore the obvious. Commercial centres have from time to time moved from one district to another, and from one country to another. The causes of these movements are often apparent. The discovery of doubling the Cape by Vasco da Gama in the year 1497 was a great blow to the ancient commerce of Venice, and generally to the industries of Mediterranean cities. This new way by water to the Indies increased the prosperity of Spain and Portugal for a time; but Antwerp, Amsterdam, and the Low Countries were much more benefited. The superior methods of distributing goods by the sea-going Dutch ships and their mechanical inventions all were contributory factors to their success.

In the seventeenth century science began to influence industry, and in this new departure Florence was conspicuous. Florence was then the very brain of civilisation, for the physical investigators of this illustrious seat of learning in the first half of the century,—Gallileo and Torricello and others,—had an immediate influence on the early steam engine, the sextant, the chronometer, and other inventions of Great Britain. Torricello invented the barometer for indicating

the pressure of the atmosphere; we had the thermometer and the pendulum and the telescope and microscope from Gallileo; and, only a few years afterwards, in Great Britain, after being thus taught to see and weigh and measure heat and cold, to examine the mysterious causes of vacuum, and to value the pressure of the atmosphere, we received the experimental engines from the Marquis of Worcester in 1663, and Savery's engine in 1698, while Newcomen invented his simple vacuum or atmospheric engine in 1712, which, we must not forget, did useful work in England for a hundred years before James Watt's double-acting engine with the conical pendulum or governor balls for controlling it became recognised and popular.

It was at Florence that the first scientific academy in Europe was founded by Prince Leopold of Tuscany, in the year 1657, and the second scientific society was the Royal Society, in London, whose charter was granted in the year 1662.

If we picture the industrial map of Europe in our imagination as it was in 1700, we find that in Great Britain, with the exception of one or two early inventions of steam engines and some improvements in watches and clocks, we were not superior, nor even equal, to the manufacturers on the Continent.

We had a small trade in London, Bristol, Sheffield, Birmingham and Manchester; but we bought all our bar iron from the Continent, for in 1676 Andrew Yarranton, who wrote on the improvement of England, said that we had no rolling mills in this country at that period, nor for many years after. We imported all our hollow-ware of cast iron; all cooking pots came from Holland. We made a few anchors ourselves, and we had a small trade in wrought-iron pans and shovels in Wigan and in the black country, and our chain smiths were very ingenious; but the iron bars came from abroad. Round and square iron was hammered to shape laboriously on the anvil, or by swages and tilt hammers, but it was poor in quality; the use of charcoal had been prohibited, and coke had not been perfected. Better methods of dyeing and bleaching were being introduced by refugees into Lancashire, as silk manufacture had been introduced in the south of England by the Huguenots some years before this. In spinning and weaving, bleaching and dyeing we were inferior to the people of the Low Countries, and about this period the Dutch loom, which was much better than ours, was introduced into Lancashire.

Paper making had been introduced by foreigners as early as the time of Henry VIII., and a few mills existed in the time of Elizabeth; but the best paper for printing books came from the Continent. Oliver Cromwell remitted the duty on the paper for printing the "Polyglot Bible," which came from Holland. Goldsmiths of Bristol and York and London were very ingenious and did some good work; but in metal and in textile fabrics, both in design and manufacture, we were very much inferior to foreign countries.

Dutchmen were engaged in the erection of water supplies and pumps, and the Norfolk Broads and the Bedford Level were finished under Dutch management, in the time of Charles the Second. Improved windmills were introduced from Holland, and the water-wheel was being brought over; indeed, the manufacturers of the Low Countries, of Haarlem, Bruges, Antwerp, and let us not forget Barcelona in cotton goods, were supreme in the commerce of Europe, especially in export trade at this particular period; Barcelona was the Cottonopolis of Europe for 1000 years before the mechanical inventions placed Manchester in that position. Barcelona was the market for raw cotton up to the year 1790, after which Liverpool gradually took this position.

Soon after the commencement of the eighteenth century Manchester and Liverpool were becoming more important and the growing industries of South Lancashire caused some of the most prominent and active men of Manchester to obtain a bill for making the River Irwell navigable to the Mersey and to the sea. This scheme was sanctioned by Parliament in the year 1720. This

increased facility for exporting manufactured goods and for obtaining the raw material from foreign countries gave a great impetus to the industrial prosperity of Lancashire.

A great export trade was springing up, and there was an increasing demand for textile manufactures, which appeared to sharpen the wits of those engaged in the trade, and the very first invention that doubled, and in some cases trebled, the production of the weaver came from a native of Bury,—the invention of the fly shuttle in the year 1733.

Before this invention for weaving we were not superior to any in the world. The mummy cloths of Egypt, the robes of the Queen of Sheba or of Cleopatra, and the tapestries of Babylon, or the vestments of the cavaliers, the garments of Queen Anne, were all spun and woven by simple tools differing very little from one another. The distaff and the spinster's wheel and rude frames called looms were the only methods known to mankind before this great invention of Kay, of Bury.

Wonderfully simple it was, a carriage on rollers propelled by a piece of string, and two pickers enabled one man to do the work of three or even four, for before this, for broad pieces, two men were employed to throw the shuttle to each other and one man to push up the beam, as described by Dyer, the poet.

"Or if the broader mantle to the task,
He chooses some companion to his toil;
From side to side with amicable aim,
Each to the other darts the nimble bolt;
While friendly converse, prompted by the work,
Kindles improvement in the opening mind."

This new system of weaving quickly exhausted all the productions of the spinsters, and their work went up to a premium, for the new looms could use more weft and warp in a day than the spinsters produced in a week. The speed of the shuttle gave it the name of the "fly shuttle." Inventors next began to consider how to increase the production of the spinning wheel. Before I allude to this let me say that Kay invented many other machines for carding or combing cotton and others, which may be seen in the Patent Museum in South Kensington. He was beset and picketed and much ill-used by those whom he benefited. He had to leave Bury to save his life, and died in poverty and obscurity in France, and it is not known where he is buried.

Kay invented a power loom, which he was unable to introduce. His brother, Robert Kay, invented the drop box for different colours to be used in weaving.

James Hargreaves, of Blackburn, and Thomas Hayes, of Leigh, both endeavoured to supply the great demand for yarns produced by Kay's new loom. I have devoted considerable time to investigate the claims of both, and am inclined to believe that independently of each other they simultaneously invented the spinning jenny. Between 1766 and 1769 Hayes produced one with six spindles, and about the same time Hargreaves produced one with twelve spindles.

The spinning jenny was very much enlarged until the introduction of spinning by rollers. These rollers, going at different speeds, elongated the fibre preparatory to its being spun. Hayes invented this in 1767, although he had been anticipated by Lewis Paul, of Birmingham, whose crude claims deserve some consideration and in 1770 Hargreaves exhibited a double jenny with twelve spindles on the Manchester Exchange, and became a man of repute among the men of Manchester who presented him with a testimonial and 200 guineas.

The next important invention was that of Samuel Crompton, of Bolton, for, with all the new inventions for spinning, it was still found impossible to fill the mouth of the new loom. Quite a famine was created, and in the year 1775 Crompton, of Bolton, invented the spinning mule. He mounted a great number of spindles on a movable carriage, which by being pushed backwards and forwards one man could do an enormous amount of work. In 1811 the government made him a grant of £5000.

The reports of the exports and imports of fine yarn about this period, up to about 1805, show that we had imported most of our fine yarns from India. Crompton's mule stopped this importa-

tion, and we began to send fine yarns back to that country. The production of Crompton's mule enabled men to earn more than ten times the wages of the poor Indian handicraftsman, and to send fine yarn at a cheaper rate than it could be produced in the home of the cotton plant. Crompton, as usual, was in great fear at one time because of the enmity of workmen. He died in 1827, and in the year 1862 Bolton erected a fine bronze monument to commemorate his name as a public benefactor.

Another new era soon commenced,—the power of these ingenious machines for spinning and weaving was about to be further increased. James Watt's new double-acting steam engine was being introduced into the manufacturing districts, and many men applied themselves to drive Kay's loom and Crompton's mule by steam power, and a Kentish clergyman, Dr. Cartwright, took out a patent for a steam loom; but the practical invention of the new weaving machines was the work of Radcliffe and Horrocks, two Stockport manufacturers and inventors, in the year 1805. Stockport is just on the border-line of Lancashire and Cheshire; but it is so near, indeed, part of Stockport is in Lancashire, that for practical purposes we will give that enterprising and much esteemed old town the benefit of the doubt. Here again another famine in yarn was created, for the moment the new steam looms began to work at enormous speed, all Crompton's mules, which were producing good work all over the county, could not supply the demand for warp and weft, and for a long period this demand for steam spinning did not produce the man.

The steam spinning machine, the self-acting mule, is probably one of the most ingenious of the many remarkable and clever appliances used in cotton manufacture. It was not until the year 1834 that Richard Roberts produced his first self-acting mule. We cannot call him a Lancashire man; but his mother was born in Liverpool, and his father was a poor Welsh shoemaker. Roberts was born at Lanymynech, near Welshpool.

Roberts, if not the greatest mechanical inventor of the nineteenth century, was the last of the great inventors of those original departures,—parent inventions for textile manufacturers. The self-acting mule is so well known that I will not go into any description. It is used extensively all over the world, and has been one of the greatest inventions that has placed Lancashire manufacturers in the front rank.

Everything that Roberts touched seemed to become alive; he had the wand and power of Prospero. Richard Roberts made dry bones live. The only difference in poets and inventors and sculptors in their art of expression is in the materials of construction used to build what is in their imagination; one builds of marble and another of solid bronze. The poet sings his melody, and in words which

> "Like the bow that spans the sky,
> Brings colours from heaven that never die."

The sculptor sees the angel or the God in the rough marble block and chisels away the covering that hides it from the gaze of man. The inventor's imagination sees the perfect machine working before he places it in black or white on paper, and the expression of his genius is in the complete invention.

Roberts has not given us poems of lyric beauty, but his art and execution had all the quality of our great poets; his fingers were the obedient servants of his opulent imagination, for his exquisite drawings were perfect. his taste was equal to his skill, for his mind and his fingers were in true partnership. He never went to school, and yet he was an accomplished mathematician, and employed the highest skill in his drawing office. He had a staff of educated men, and was very exact; he would not permit experimental work to proceed until high-class detailed drawings were all made. I knew him as a boy, and it was my good fortune often to see him. He always said that a piece of black lead pencil and paper were far cheaper materials for experiments than making rough models without any proper scheme in black and white on the drawing board.

Roberts invented the slide lathe, and

the first one is working at the works of Messrs. Beyer, Peacock & Co., at Gorton. The carriage of the lathe is on the front of the bed and not on the top, and this idea is coming again to the front in some American and German lathes I have seen recently.

He also invented the planing machine for planing metals. I remember seeing some of the early ones driven by hand with a barrel and an endless rope; a man turned round when he got to the end of the stroke and with a windlass wheel pulled the carriage back again. Afterwards more complete machines were made, chiefly driven by chains. These, again, were much improved by William Muir and Sir Joseph Whitworth. I know, about the same time Fox, of Derby, is said to have invented the planing machine; but I think Roberts was a little earlier in the field. Maudslay had invented the slide rest in London, and Roberts had been working there as a young man, and having seen the slide rest, when a long job had to be turned, it was almost natural for an ingenious man like him to invent the slide lathe.

Roberts invented an automatic emery wheel, with a slide arrangement for grinding and polishing,—very accurate and beautiful in its action,—similar to those that have been invented of late in America and sold in England as novelties. I worked one when I was an apprentice. He brought out some of the early slotting machines, and a pentagraph automatic drilling machine for drilling holes without the use of a centre punch. A dummy or model was placed in position; the drilling machine then imitated it on a piece of metal, and drilled as many holes as the model had. He took out many patents for weaving carpets. He invented a reed-making machine. He designed twin screw propellers,—one called the *Flora*, as a blockade-runner in 1862, which could turn in its own length, and was the forerunner of that type of steamboat. He designed the first locomotive made in Manchester,—practically the modern locomotive. His jacquard punching machine for punching the plates of the Brittannia Tubular Bridge,—mezzotinted in metal, if I may coin a word,—does what the jacquard loom does for silk. By placing a card in the punching machine he would punch holes to any pattern, even a portrait.

This punching machine was used for the Menai, the Conway, the St. Lawrence, the Victor Emanuel, and many other tubular bridges. His firm, Sharp & Roberts, made them for Messrs. Peto Brassey & Co. His improvements in electro-magnets, timepieces and watches, in weaving, in automatic valves and water meters, ventilators for boats, the modern swivel anchors now in use, engraving machines, and a host of other appliances would take a long time to describe; but his self-acting mule was his greatest achievement, which he designed and made in thirteen weeks.

He died poor, although the men of Manchester agreed to allow him £1000 a year if he would come to live in Manchester, for he had gone to reside in London, and lies buried in Kensal Green Cemetery. I hope some day we may have a monument in Manchester to commemorate the great benefactions of this greatest English inventor. When a boy I was permitted to go about in the works of his last firm, Roberts, Fothergill & Dobinson. The works had an armoury in Falkner street in 1857, and loopholes were over the gates to enable the place to be defended from attack.

John Wilkinson, the inventor of the first iron boat, which was placed on the water in 1786, was born in Cartmeal. The influence of this invention on our mercantile marine has been enormous, self-evident, and apparent; but the invention was for a long time waiting for the tools to be invented before it could be manufactured on a large scale, and then it became a formidable competitor with the wooden boats of the United States and other countries.

Even so recently as 1850 the United States had the fastest and largest ships in the world. Many of us will remember that the clipper sailing ships brought the first cargo of tea from China round the Cape, and brought the cotton supply from the Southern States to Liver-

pool, and Canadian timber and other wood in abundance, and at that period our total tonnage of mercantile ships was about equal to that possessed by the United States. Since that time our fleet of sailing vessels and steamships, chiefly steel, has become greater than the combined fleets of the nations of the world. Cheapness in production must be the cause of this.

Wilkinson and his father took out a patent for box irons for laundries. They were too poor to have a foundry of their own, and therefore bought the molten metal from a little foundry opposite their workshop. Wilkinson hawked their productions, and in course of time became prosperous. He is a somewhat isolated instance of a wealthy inventor; he died worth probably about one million sterling. He invented the hot blast for iron melting and the steam blower, and made the first boring machine for engine cylinders, for he had been making cannon and had invented boring appliances, and, coming in contact with James Watt, they became great friends.

Some of the early engine cylinders before Watt's time were not bored at all. The Newcomen engines were made in semi-circular castings, in halves, like rain water guttering, and were then bolted together. I have seen a copy of a letter in which James Watt says, with great delight, that by using Wilkinson's boring machine, he has obtained some engine cylinders that are not more than ⅛ inch diameter larger at one end than at the other. This very energetic and clever man had works at Warrington, Bilston, and in the neighbourhood of Wolverhampton. His brother-in-law, Dr. Priestley, of Birmingham, the discoverer of oxygen, was born in Cheshire and afterwards went to Birmingham.

William Sturgeon, another Lancashire inventor of note, was born near Lancaster, his father being a shoemaker. Young Sturgeon was apprenticed to the trade, and to escape ill-usage he enlisted in the Westmoreland Militia, and later on was a private soldier in the Second Battalion of the Royal Artillery. When stationed at Newfoundland with his regiment he began to study thunderstorms, lightning, and electricity. The sergeant of his company lent him books, and, according to the late Dr. Joule, who has written a short memoir of him, when a soldier he devoted considerable time to the study of mathematics and the dead languages and optics. He became somewhat of a lithographic draughtsman, and kept up his old trade of shoemaking. When discharged in 1825 he devoted some time to scientific researches and bought an old lathe and taught himself turning. In 1825 he presented to the Society of Arts his first soft iron electro-magnet, for which he was awarded a premium of thirty guineas and a silver medal. According to Dr. Joule, Sturgeon discovered the soft iron magnet in 1823, although he did not publish an account of it until 1825.

He also invented amalgamating zinc plates with a film of mercury as now used in the Leclanché and other electric batteries. In 1832 he constructed an electro-motor, the first contrivance to transmit mechanical force by electrical wires. He invented the commutator, and sent a description of it to the Royal Society; but for some reason the memoir was not accepted, and was returned to him by the Society. He afterwards published it by subscription. He came to Manchester in 1838, and was superintendent of the Royal Pictorial Gallery of practical science. He hawked the portable magnetic machine for medical purposes at one time, for his poverty was very great. After young Joule left Dalton, Mr. Joule, Senior, consulted him as to what was the next thing to do. Dalton said that by all means he should go and have a course of scientific training with Sturgeon. I obtained this interesting bit of information from a venerable relative of Mr. Joule, Senior, a short time ago.

He contributed to *Bradshaw's Manchester Journal*, published in 1842. He lectured at the Mechanics' Institution and Salford Lyceum, and lived in a poor way in this district. He started a journal called the *Annals of Electricity*, and to this journal Dr. Joule contributed various papers. The first Bishop of Manchester, Dr. Lee, Mr. Binney, and

the Literary and Philosophical Society in 1850 petitioned the government in consequence of his poverty, and Lord John Russell's government granted Sturgeon £200 and an annuity of £50 per year, which he enjoyed for only fifteen months. He died poor, in 1851, aged sixty-seven, and lies in Prestwich Churchyard.

This great man's life was one perpetual struggle with adversity. He was highly appreciated in his lifetime by men mostly as poor as himself, but we who are blest by his labours may remember him with reverence when we see the electric light or the rapid electric cars; or when we respond to the tinkling of the bell which summons us to use the telephone, for all are evidences of his invention of the soft iron magnet.

The invention of the puddling furnace by Henry Cort, of Lancaster, caused great improvement in the quality of manufactured iron. Previous to the year 1783 no English iron was used for the purposes of the British Navy. As much as £35 a ton was paid for Russian or Swedish iron, for English iron was bad in quality, and as a means of removing the impurities from it, the furnace met with immediate and remarkable success. When Cort took out his patent, the best iron came from Sweden. Small quantities were made in England by charcoal furnaces, but the invention of Cort's puddling furnace stopped the importation of wrought iron. The ironmasters willingly agreed to pay a royalty of 10s. per ton. Cort's rolling mills with grooved rollers were also of great service in producing a more uniform bar. The production of iron received a great impetus from his inventions, as it was only 90,000 tons per annum when his invention was introduced; in the course of two or three years it rose to five millions per annum. Ninety years afterwards we exported thirty-eight millions in value per annum. Cort died poor, chiefly through unfortunate partnerships.

The steam hammer by Nasmyth is so well known that there is no necessity to describe it. The hammer was designed at Patricroft in obedience to the increasing demands for larger forgings, although uncouth and difficult tilt hammers had been used with steam power before this period. The chief quality of the invention of Nasmyth was the valve that enables the hammer to be brought down on the hot metal with great precision.

The paddle shafts for the steamship *Great Britain* were being made in 1838, and Mr. Nasmyth was requested to consider the dilemma, for no tool was large or strong enough to produce the forgings. Nasmyth at that time brought out his hammer. I remember my father telling me that in 1851 there was one shown in the great exhibition in Hyde Park, and he saw it come down with great force on the top of a gold watch, the blow being regulated with such delicacy that the hammer struck and held the watch so that it could not be moved and did not break the glass. Nasmyth was a Lancashire Scotchman, and came as a young man to Manchester, and the story of his life has been well told by Mr. Smiles in his industrial biographies.

Dr. James Prescott Joule was born in Salford in the year 1818. In addition to having discovered the mechanical equivalent of heat, he was the first to invent electro-welding, and his investigations in electricity generally have been of considerable scientific value; but his great work will always remain the discovery of the mechanical equivalent of heat. His name is placed among mechanical inventors, for it would have been impossible for him to obtain his results if he had not, with great ingenuity, invented the mechanism that proved the accuracy of his theories.

Professor Tyndall describes his work with some eloquence. He says:— "Those who are acquainted with the details of scientific investigations have no idea of the amount of labour expended on the determination of these numbers on which modern calculations or inferences depend. They have no idea of the efficients shown by a Berzelius in determining atomic weights; by a Regnault in determining expansion; or by a Joule in determining the mechanical equivalent of heat. There

is a morality brought to bear upon such matters, which, in point of severity, is probably without a parallel in any other domain of intellectual action."

There is a monument, to commemorate his services, in Manchester, and his name will live for evermore in the classics of science and in the class books of the young engineers and electricians of the world.

Litherland, of Warrington, invented the lever watch in the year 1791. A great trade in chronometer movements had gradually grown up in the neighbourhood of Prescot and Warrington, and watchmaker's tools of excellent quality are still produced at Warrington. Although Reid, in his book on clocks and watches, says that it was invented in France, I have compared the drawings in the patent specifications and find that the patent lever watch in its simplicity and utility was invented by Litherland. He also invented a keyless watch, but I am unable to say if it was the first.

The typewriter was first invented by William Hughes, a Manchester man, the first master and governor of Henshaw's Blind Asylum, in 1850. This instrument was originally brought out for the use of the blind. The types striking the paper were made of steel, causing the letters to be indented on the paper, so that they could be easily read when touched by the sensitive fingers of blind persons. This typewriter was somewhat extensively used when first brought out. There is one in the Victoria and Albert Patent Museum at London. Since Mr. Hughes' death the ink roller has been added, and the modern typewriter is the result; but the actual details of the present typewriter may be found in this original invention of the ingenious first governor of the Blind Asylum.

John Ramsbottom's name is well known in connection with the London & North-Western Railway. He was for many years the chief engineer of the company, and he invented the well-known double safety valve for locomotives known by his name. He was born at Todmorden, in the Lancashire end. Most readers are probably well acquainted with the very ingenious arrangement for feeding locomotive tenders with water whilst the train is in motion. This was the invention of Mr. Ramsbottom.

He also made many improvements in looms, and invented the weft fork stopper for weaving. The weft fork is a simple invention, but of immense value to the power loom, for its automatic action stops the loom when the weft breaks, and has much reduced the cost of production.

I think his condenser lubricator is one of the most ingenious inventions about a steam engine. Its simplicity consists in filling a brass cup with oil; steam is admitted which condenses, and a drop of water descends from the top of the cup into the oil, displacing the same amount of oil, which then slowly passes into the cylinder or steam chest. When the cup becomes full of water, this is drawn off and replaced with oil.

British commercial eminence owes much to these Lancashire inventors, whose work I have endeavoured to describe, and whose genius has changed the entire face of Great Britain and increased British national prosperity. Is it not very pitiable, when we consider their melancholy history, that most of these benefactors have been martyrs, that the communities they most benefited brutally ill-treated them from the time of Kay, of the fly shuttle, whose invention consolidated the Lancashire cotton industry, on to Richard Roberts, the inventor of the self-acting mule, whose buildings were defended by two arsenals of guns and pikes?

Let us for a moment consider our present commercial position, and in doing so remember this, which I desire again to emphasise, that we are the last comers, that we have had possession of our chief industries, as leaders, for only little more than half a century. The Lancashire manufacturers at the end of the eighteenth century bought their cotton in the chief city for the raw material and finished goods,—Barcelona, and not in Liverpool. We have been

makers of bar iron for little more than a century; before that period the Continent produced superior metal.

The opposition to improving machinery in the silk trade,—machinery, by the bye, of our own invention, with the one exception of the Jacquard loom,—has driven the bulk of the trade to the Continent; indeed, the silk weavers of Lyons are better paid than ours, they receive higher weekly wages, and this we have on the authority of Sir Thomas Wardle, who attributes the decay of our silk manufacture to neglect in not adopting labour-saving mechanism. We had a large silk manufacture here at one time, and when I was a boy there were many mills in Manchester and Salford. At present the tools that Lancashire men have invented are being refined by Germany and the United States, and because of the freedom of labour there, in many cases, they are used to better advantage than they are in this country, where restrictions, limiting output, are imposed by labour combinations.

I can specify goods made abroad that are being sold in Manchester and London that it is nearly impossible to make in this country and sell at the same price, and yet the tools that are used to produce them were invented by men of Lancashire.

Our stupid patent laws are doing our industries a great amount of injury. They were originally created to encourage and reward original genius in this country and to stimulate British trade, for which see the preamble of patents of the time of Charles the First; but we know that if a foreigner takes out a patent here, he can manufacture his goods abroad and send them to this country, as in the case of aniline dyes and other chemical products. A change in the laws in that respect is imperative, and would be of great benefit to the chemical and other industries of Great Britain. All British patents should be for goods made in Britain and to benefit British industry; otherwise the grant of a monopoly to attack us is a farce and cannot be defended.

The Manchester Ship Canal has done something for the export trade, but rings have been created that give the foreigner the use of British ships at a cheaper rate than our own citizens. For instance, last year cotton goods were sent from New York to China, calling at Liverpool, at 27s. 6d. per ton, while Manchester men paid 55s. by the same boat. There is a cure for this. One is that no government mail subsidies should be given to ships that thus place us at a disadvantage.

In steamships we need not despair. Great Britain is still mistress of the seas. I think we may be satisfied that we produce them and are unrivalled in price and quality. There is no necessity for us to imitate the daughters of Zion and sit by the waters of Babylon lamenting the past glories of our country. Let us just examine the figures for one moment. Mr. Baker, the president of the Atlantic Transport Line, in a report some time ago, dealt with the cost of shipbuilding in Great Britain and America, and he compared the building of two ships by Harland & Wolff, of Belfast, with two ships from the New York Shipbuilding Company, of Camden. The English steamships cost £292,000 each, and those built at Camden, similar in size and tonnage, cost £380,000 each. Two smaller boats built in America cost £150,000 each, and similar boats were obtained from Harland & Wolff, one costing £110,000 and the other £100,000.

If we compare the total tonnage of steamships of the world it amounts to 22,000,000 tons, of which Great Britain owns 12,000,000 tons. The sailing vessel figures are somewhat similar; of 5,000,000 tons Great Britain owns nearly one-half. Our position in other respects is well maintained.

In education, a stern chase is a long chase, when ignorance is the enemy. Ignorant, well-meaning piety has much impeded scientific teachings; but public opinion now demands that we must rationalise education and stop the great waste of energy in the schools of this country. Complacency is the bane of Englishmen; but none can be vain who compares the industrial education given in the United States, in Germany, and

even in Hungary, with much of the aimless work that we call education in Great Britain.

Let us not blame workmen overmuch for the decay of certain industries, for some of our handicraft trades are getting old and we do not specialise as some of our competitors do. One machine works cannot make all things cheaply in small quantities. This difficulty must be surmounted by that system and division of labour that has been so successful in the cotton manufacture, and which exists to some extent in the manufacture of looms, for a Lancashire loom is the cheapest machine in the world. This system is also successful in the manufacture of British sewing machines, which are made here quite as cheap, or cheaper, than they are made abroad.

The clock trade of the United States is a triumph of organisation and an example of dear labour and automatic tools producing cheaply. The pioneer was Chauncy Jerome, who went from the Black Forest to the States. He designed sheet brass clocks, made like the wooden ones of Germany; he ordered the wheels and frames to be stamped in Birmingham, and, after putting them into cases, sent them back to Great Britain and beat us in price.

We have seen how industries have moved from place to place in Europe, and that cunning, dexterity, industry, enterprise, and cheapness all influence the change. Our commercial culture is no longer being neglected. Noble technical schools are sharpening the wits of labour, and education is being rationalised. This must strengthen our position, for those who have compared our schools with those of our trade rivals feel dismayed at our deficiencies; indeed, all our courage and ability will require scientific guidance if we are to maintain our position.

The future should be less difficult than the past; indeed, it should be easier for those who follow us, for we inherit pluck and the art of overcoming difficulties, precious hereditary qualities that are recorded in the history of the world's explorers, and which have made our axes ring in Canadian forests, sent our ships to unknown seas, and made the sound of British steam whistles heard beyond the sacred Temple of Isis, on the banks of ancient Nile.

Material progress is not the only reward, not the only product, that we receive from the labours of our men of genius, from our great inventors, for the results would be of little value if they did not lighten the burden of labour. We know and have faith that the chief achievements of the harnessed serfdom of Nature's forces temper the serfdom of man and create some leisure from the hours devoted to his mere physical needs for the higher and nobler pursuits of intellectual citizenship.

Napoleon said:—"The tools to him that can handle them" (*La carrière ouverte aux talents*). He also said that the steamboat, in his opinion, "is destined to change the entire face of Europe."

Lancashire men have changed the face of the world and altered the map, and also the class books of the students of all the seats of learning throughout the globe. Dalton discovered the law of the conservation of the chemical elements, and Joule discovered the law of the conservation of energy. In the eloquent words of Dr. Osborne Reynolds:—"It is to the memory of Joule that mankind owes its gratitude for the grandest generalisation in the universe,—the complete mechanical foundation of physical science."

The laws of the Manchester prophet tell us that all investments of pluck, of energy, of hard work and loyalty bring ample recompense, that work done squarely and unwasted days in due time produce rich harvests.

Longfellow grasped, with poetic instinct, the inner meaning of this law.

"Nothing shall perish utterly
But perish only to revive again
In other forms, as clouds restore in rain
The exhalations of the land and sea.
Men build their houses from the masonry
Of ruined tombs, the passion and the pain
Of hearts that have long since ceased to beat again
Will throb in hearts that are or are to be."

LOCOMOTIVE TYPES OF GREAT BRITAIN

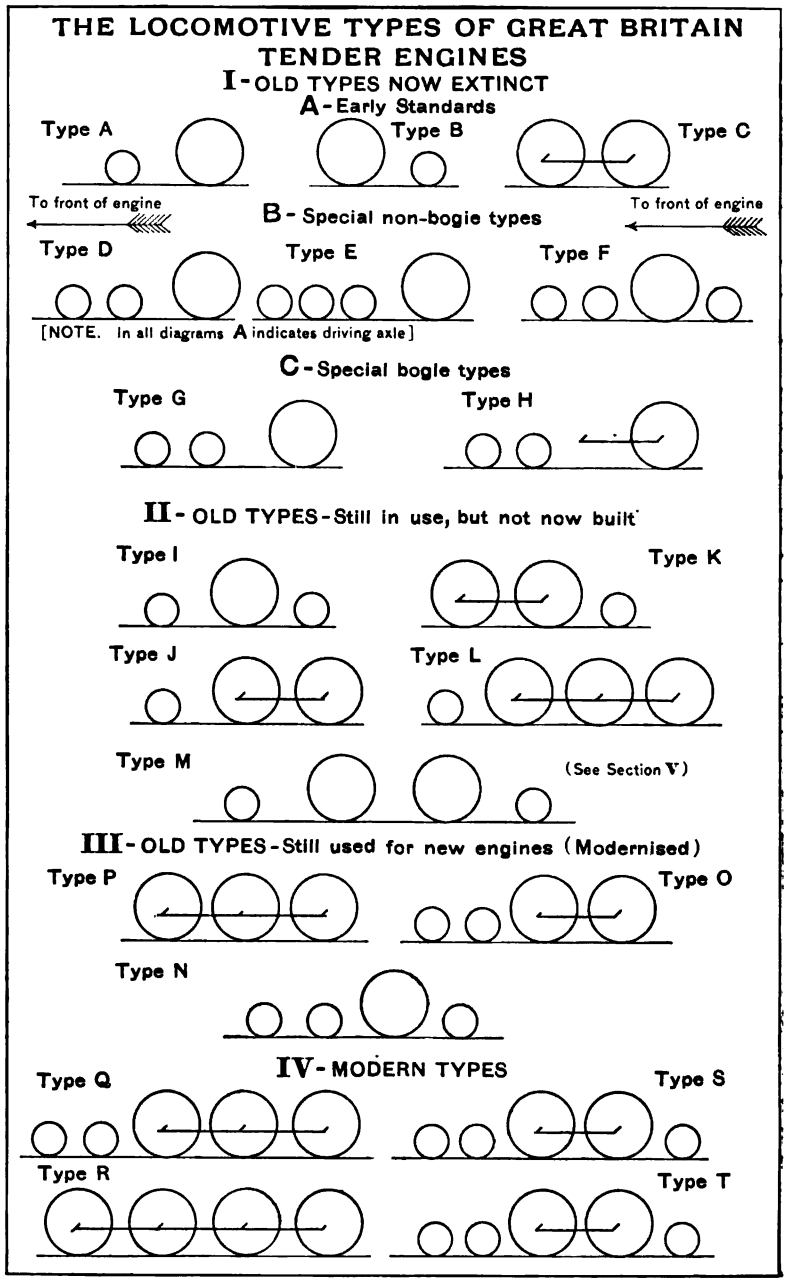
By J. F. Gairns

IN April, 1901, an article appeared in this magazine, entitled "Modern Types of British Locomotives:—A Review of Design and Performance," by Mr. C. J. Bowen-Cooke, author of "British Locomotives," and a well-known authority on British railway affairs, especially when the London & North-Western Railway is concerned, in which the latest types of British locomotives were reviewed and particulars of their work given in many cases, the older types receiving passing mention.

Articles of this kind are sometimes calculated to give the impression that these modern creations of the locomotive designer's art are the rule on our railways, and the older machines are passed over; whereas, in fact, there are at least as many of the older,—I use the term comparatively, of course,—engines at work on good trains as there are new engines, and there are, in reality, only a few trains on which the most up-to-date engines are exclusively employed. Indeed, instances occur every day of engines which ought, according to all rules and theories, to be overloaded, doing wonderful work. As an example, Mr. Ivatt's huge ten-wheeled express engines on the Great Northern Railway are intended to deal with the very heavy Scotch dining-car trains; yet on more than two or three occasions the writer has known the trains to be hauled alone by "single" engines designed by the late Mr. Patrick Stirling. Again, it is

LONDON, CHATHAM & DOVER ENGINE, ORIGINALLY TYPE "H," NOW TYPE "O"

PHOTO BY O. C. OWENS


THE LOCOMOTIVE TYPES OF GREAT BRITAIN
TENDER ENGINES
I - OLD TYPES NOW EXTINCT
A - Early Standards
Type A
Type B
Type C
To front of engine
To front of engine
B - Special non-bogie types
Type D
Type E
Type F
[NOTE. In all diagrams A indicates driving axle]
C - Special bogie types
Type G
Type H
II - OLD TYPES - Still in use, but not now built
Type I
Type K
Type J
Type L
Type M
(See Section V)
III - OLD TYPES - Still used for new engines (Modernised)
Type P
Type O
Type N
IV - MODERN TYPES
Type Q
Type S
Type R
Type T

GREAT WESTERN EXPRESS ENGINE. TYPE "I"

PHOTO BY O. C. OWENS

not unusual to find the 6-foot 6-inch four-coupled engines on the London & North-Western Railway on the best trains. It must also be remembered that, after all, there are, in most cases, comparatively very few of the latest "monsters," and nearly all of the best work must therefore be done by the other engines.

It will thus be seen that while the newest locomotives must take first place, there are thousands of other engines which possess almost, if not quite, as great an interest for us, and the writer, therefore, proposes reviewing all the types at present in use, commencing with a few notes relative to the early types now extinct, so as to present a fairly complete survey of the locomotive types of Great Britain.

To facilitate description, the sheets of diagrams on pages 314 and 318 have been prepared. On these are shown the wheel arrangements, by which the types are principally and most conveniently differentiated, of the non-compound, two-cylinder types, and the wheel and cylinder arrangements of the compound and multi-cylinder types.

I. OLD TYPES NOW EXTINCT

It is not necessary to refer to the types which preceded the opening of the Liverpool & Manchester Railway, for until the Rainhill contest of 1829, when George Stephenson's *Rocket* proved victorious, the locomotive was a clumsy, lumbering, complicated, slow-moving machine, without any particular type-characteristics, unless the amount of mechanism above the boiler be reckoned as such. With the *Rocket*, the locomotive assumed definite form and became suitable for fast work, thus inaugurating what may be termed the era of passenger travel.

At first the locomotives were provided with four wheels only, and were of types *A*, *B*, and *C*, the first two being designed for passenger work and the last for goods traffic. The *Rocket* belonged to type *B*, but type *A* engines were the more general; hence that type has been placed first. After a few years larger

A MIXED-TRAFFIC ENGINE ON THE GREAT EASTERN RAILWAY. TYPE "J"

PHOTO BY H L. HOPWOOD

engines came into use, having additional wheels, and we thus come to the second section, that of "old types still in use, but not now built," the four-wheel types *A*, *B*, and *C* developing to the six-wheel types *I*, *J*, and *K*, with a new heavy goods type *P*. Later this became the ordinary goods type. But before considering these new standards the writer will refer to a few of the special types which the early years produced and which have now disappeared.

First, as to the special non-bogie types:—In the early days there was almost a mania for big driving wheels, and some of the most interesting of the big-wheel engines of special type are those known as the "Cramptons," thus named after their introducer. The main feature of this design consists in placing the driving wheels,—7 and 8 feet in diameter,—behind the fire-box, all the carrying wheels, four or six in number, being in front. A number of these engines were built, and their character was "good." As, however, engines equally as "good" soon appeared, of orthodox designs, the "Cramptons" gradually passed into oblivion, so that to-day there is not a single engine of this kind left in Great Britain, and it is questionable whether there are any anywhere else, unless we except a few relics remaining in France where the type was a favourite one, or in other countries to which they were supplied at their time. Types *D* and *E* on the diagram on page 318 are the "Cramptons."

On the Great Western Railway there were very many eight-wheeled (not bogie) single driving engines of type *F* with 8-foot wheels. These engines were famous and worked on the broad gauge until its abolition in 1892.

Of the "bogie" special types of the past, type *G* is that of the several engines supplied for working the Lickey incline of 1 in 37 for several miles on the Birmingham & Gloucester (now the Midland) Railway in 1840. These were the first bogie engines in this country, with the exception of some curious engines which worked on the Dundee & Newtyle Railway in 1833 with single leading wheels and a trailing bogie.

Type *H* represents a modification of the type *D* "Cramptons." In this design there was a dummy-shaft driven by

the engine, coupled to the driving wheels. These engines were used on several railways, but in one case at least they were always running off the lines and were absolutely unsafe at high speeds. This was on the London, Chatham & Dover Railway. The engines, later, had a second pair of wheels fitted on the dummy shaft, thus converting them to bogie four-coupled engines of type *O*. Two or three of these were in existence quite recently, and they can be distinguished by the fact that the bogie is cramped in very close to the driving wheels

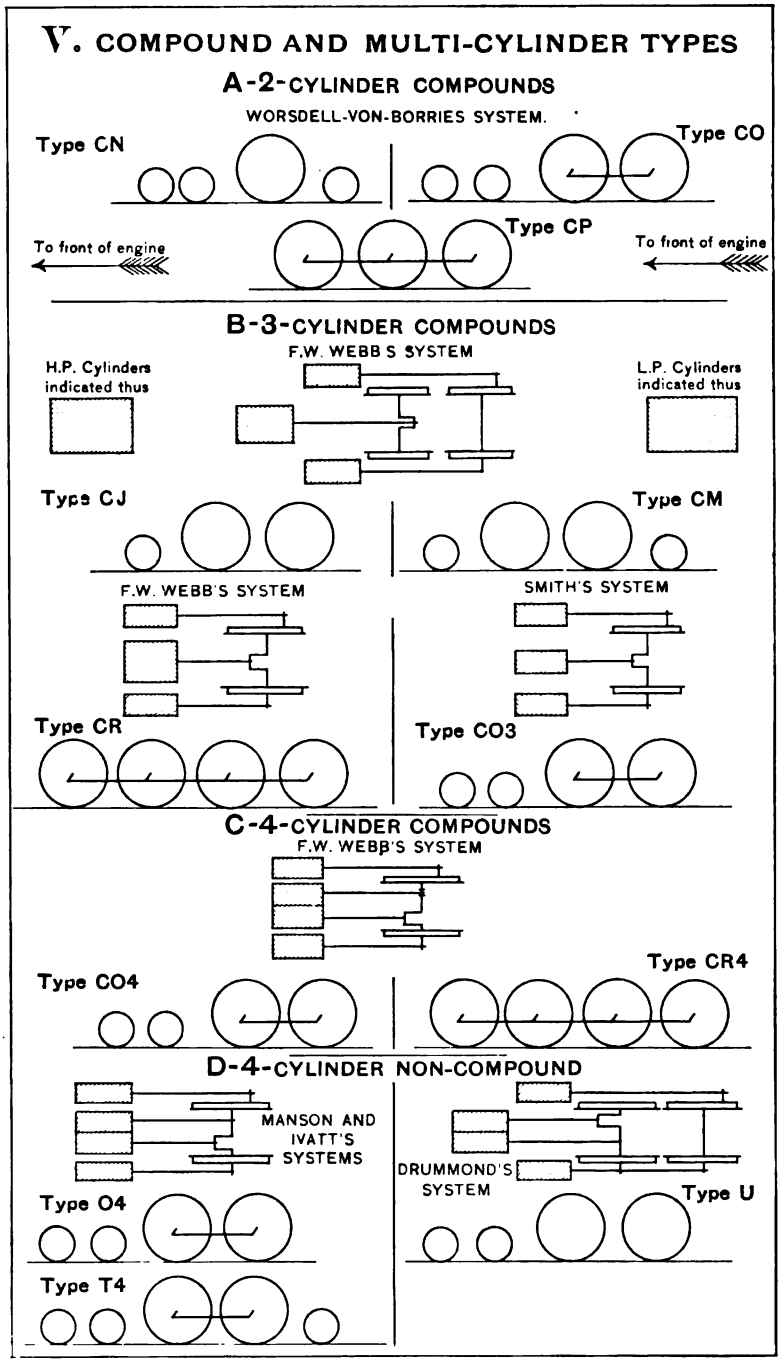
II. OLD TYPES STILL IN USE BUT NOT NOW BUILT

Reference has already been made to the early supersession of the old types *A*, *B*, and *C* by their developments, types *I*, *J*, and *K*,—types which, in their turn, are now reckoned old, though modernised, for none of them is now counted as up to date, nor is still a building type in Great Britain. In the course of years the old single engines, type *I*, which succeeded the four-wheel types *A* and *B*, were replaced by larger and more powerful engines, and as time went on the four-coupled types *J* and *K* ceased to be reckoned as goods engine types, and were included in the passenger list, except that those with smaller wheels were classed as "mixed-traffic" engines. And now we find on most railways single driving engines of type *I* in considerable numbers, still doing good work, yet taken off the best trains in almost every instance. And thousands of type *J* engines are working trains of all sorts,—in some cases the best,—but, as a rule, second-rate; while type *N* is a very useful "mixed-traffic" type, used extensively on several railways, and as an express type on one railway.

A LONDON & NORTH WESTERN EXPRESS ENGINE. PRECEDENT CLASS. TYPE "J"

PHOTO BY J LAKE

The most recent of type *I* engines to


V. COMPOUND AND MULTI-CYLINDER TYPES
A-2-CYLINDER COMPOUNDS
WORSDELL-VON-BORRIES SYSTEM.
Type CN
Type CO
Type CP
To front of engine
To front of engine
B-3-CYLINDER COMPOUNDS
F.W. WEBB S SYSTEM
H.P. Cylinders indicated thus
L.P. Cylinders indicated thus
Type CJ
Type CM
F.W. WEBB'S SYSTEM
SMITH'S SYSTEM
Type CR
Type CO3
C-4-CYLINDER COMPOUNDS
F.W. WEBB'S SYSTEM
Type CO4
Type CR4
D-4-CYLINDER NON-COMPOUND
MANSON AND IVATT'S SYSTEMS
DRUMMOND'S SYSTEM
Type O4
Type U
Type T4

be built for British lines are those of the Great Eastern Railway, dated 1888 and 1893, with 7-foot driving wheels; and yet two or three of them have already been broken up, and the rest have been put on country work, thus showing, in a very marked manner, the immense increases in the weight of trains during the last few years. Indeed, these "singles" have not only been superseded themselves, but their successors of 1898, large bogie singles of type *N*, have also been relegated to country work, although both classes have done splendid work with very heavy trains.

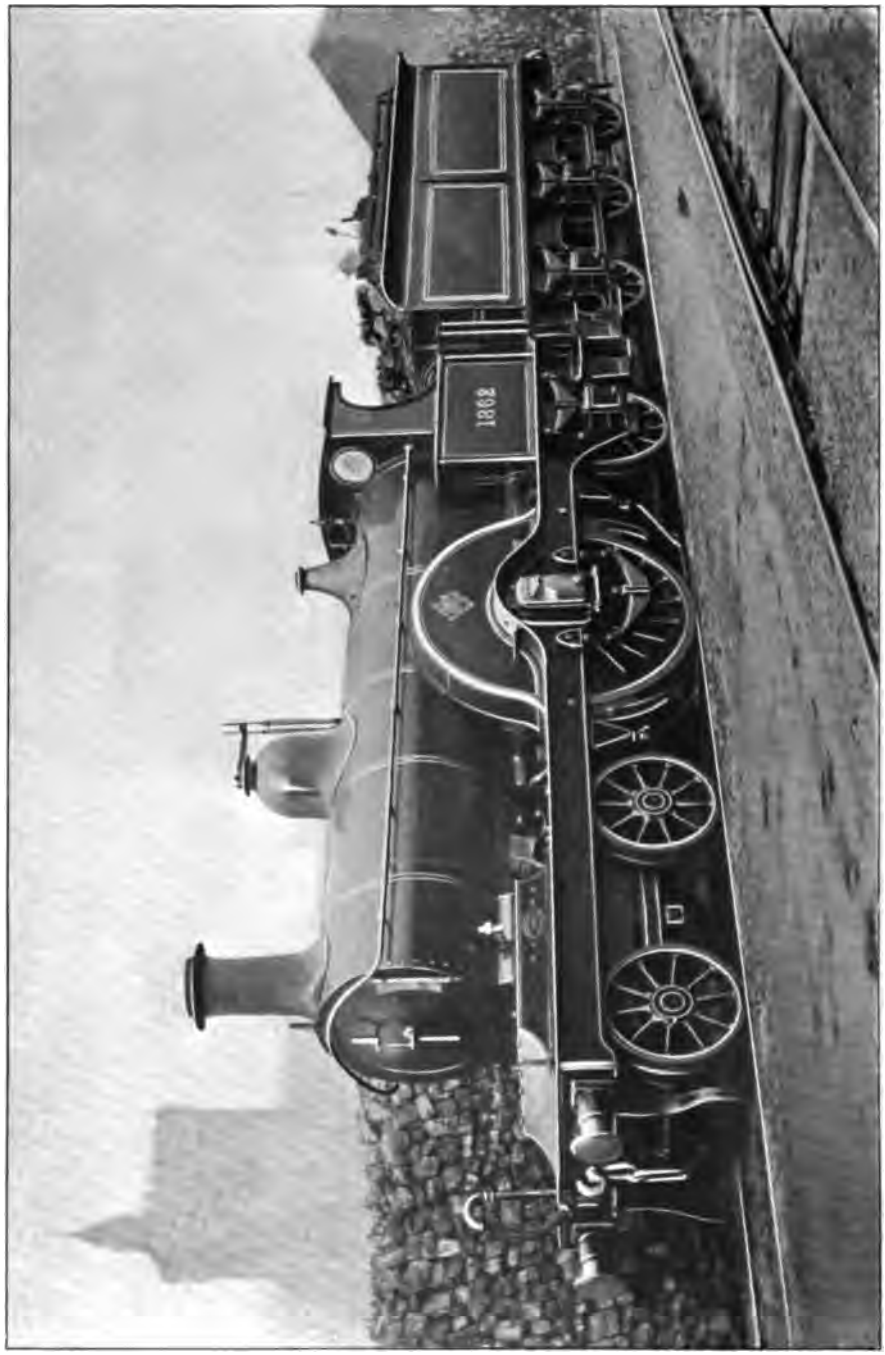
LONDON, BRIGHTON & SOUTH COAST RAILWAY EXPRESS ENGINE. GLADSTONE CLASS. TYPE "K"

PHOTO BY H. L. HOPWOOD

The Great Northern Railway, with Mr. Stirling's 7-foot 6-inch singles, is the only railway which still uses these engines on anything like first-class work, though the London, Brighton & South Coast Railway sometimes uses its little 6-foot 6-inch singles on such trains as the 2 P. M. Pullman Express from London Bridge to Brighton, and that on a Saturday afternoon, too. On the London & North-Western Railway the singles are used principally as pilot engines and on branch line work.

The four-coupled engines of type *J* rank next to the six-coupled goods engines of type *P* as regards universality, for with the exception of the London, Brighton & South Coast Railway and the London & South Western Railway, which have a very few only, if any at all are left, they are possessed in considerable numbers by all railways, many of the engines being of comparatively recent date, and used on the best work. This is notably the case on the Great Eastern Railway with the 7-foot four-coupled engines (the 700 class), and the 5-foot 8-inch mixed-traffic engines (the 420 class); and on the London & North-Western Railway with the 6-foot 6-inch ("Precedent"), and 6-foot engines, known familiarly as "Big" and "Little Jumbos," respectively.

Yet except in one very recent instance, which bids fair to be the last, the type must now be reckoned as one of the past, certainly for express work, and practically for mixed-traffic work, having been superseded by the bogie type *O*. The recent instance referred to is the building of ten new mixed-traffic engines on the Great Eastern Railway, type *K*, which appeared at one time to be in favour with many locomotive superintendents; but this does not seem to be the case now. On the Great Northern and London & South-Western railways there are several hundreds of these engines with 5-foot 6-inch and 6-foot wheels for mixed-traffic work, but none of them have been built for



AN EXPRESS ENGINE OF THE MIDLAND RAILWAY. TYPE "N"

PHOTO BY O. G. OWENS

many years and it seems unlikely that there will be any more of them. Many railways possess engines of this type, but only one reckons them as express engines. That is on the London, Brighton & South Coast Railway where the late Mr. Stroudley's "Gladstone" class of front-coupled 6-foot 6-inch engines were at one time the crack engines of the line, and are even now often used on the best trains.

Type *L* is a modification of the 6-coupled goods type *P*, generally known by the American name "Mogul," which, in years gone by, has had several representatives, a few of which may still be in use, but is now represented only by the American engines supplied a few years ago to the Midland, Great Northern, and Great Central railways, and which have been responsible for so much discussion, and by a few big goods engines on the Great Western Railway. Type *M* will be considered in Section V as a compound type, *CM*, for it is not used at all for "simple" tender engines.

III. OLD TYPES STILL USED FOR NEW ENGINES (MODERNISED)

The bogie singles of type *N* date back to the sixties, but its representatives were very few until the late Mr. Patrick Stirling brought out his famous 8-footers on the Great Northern Railway in 1869. Even then the type did not come quickly into favour, but after a few years it was adopted by many lines, notably the Midland, Great Eastern, North-Eastern, and Great Western. Now the type seems to be nearing its termination, for although the Great Eastern, Midland, Great Northern, and Great Central railways have some very recent engines of the type, which, except in the case of the first of these lines, where the engines concerned have already been sent out of London, as before mentioned, are still on some of the heavy express trains of to-day; yet all three lines are very extensive users of coupled engines, and on the Midland and Great Central railways there are coupled engines of later design than the recent singles.

The four-coupled bogie engines of

SOUTH EAST COAST RAILWAY GOODS ENGINE. TYPE "P"

PHOTO BY O. C. OWENS

A GREAT NORTHERN RAILWAY EXPRESS ENGINE. ATLANTIC TYPE. TYPE "S"
PHOTO BY H. L. HOPWOOD

type *O* are so common and well known that it is hardly necessary to refer to them. There are comparatively old engines of the type, and there are very modern engines in large numbers on nearly every railway. The six-coupled type *P* is practically universal in its use. It is the standard type for goods traffic on every railway, and, therefore, needs no extended mention. Suffice it to say, that although intended and built for goods traffic, these engines are used extensively for passenger work. Indeed, on the London & North-Western Railway the six-coupled engines rank almost as mixed-traffic engines, and in some cases as express engines. According to qualified observers, these engines have been used several times north of Crewe on the celebrated Manchester expresses, and have kept time, too. The writer has himself seen them on goods express trains near London.

IV. MODERN TYPES

We come now to the essentially modern types, and here the writer touches on ground already covered by Mr. Bowen-Cooke in his previously mentioned article, so that slight reference only is required.

For many years ten-wheeled, six-coupled bogie engines (type *Q*) have been standard express engines in America and on the European Continent, but it is only recently that they have come into favour in Great Britain. Now, however, six-coupled express engines with 6-foot and 6-foot 8-inch wheels are used for working heavy express trains on the North-Eastern main line, even on the comparatively level York-Newcastle section. The Great Western Railway has introduced them, with 6-foot 8-inch wheels, for the gradients of Devon and Cornwall, the Highland Railway uses them for passenger work (5-foot 9-inch wheels) over their Scotch gradients,—just the place for them; and the Caledonian Railway has just placed some peculiar inside cylinder engines (all the others have outside cylinders) with 5-foot wheels, the front coupled wheels being the drivers instead of the middle pair, as usual, for working over the very

A GREAT NORTHERN EIGHT-COUPLED GOODS ENGINE. TYPE "R"
PHOTO BY H. L. HOPWOOD

heavy gradients of the Callandar & Oban line,—again an ideal ground for them. It appears likely also that the Great Central Railway will be the next to adopt the type.

Type *R* represents the eight-coupled goods engines which are now being introduced extensively on British railways where traffic is very heavy. At present the North-Eastern, Caledonian, and Lancashire & Yorkshire railways use non-compound engines of the type, and the London & North-Western Railway has compound engines with either three or four cylinders (compound types *CR* and *CR4*).

Types *S* and *T* are alternatives used by British railways where a very powerful machine is required, and where, at the same time, it is not desired that three axles shall be coupled. These are practically the eight-wheeled type *O* with an additional pair of trailing wheels. Two railways only have introduced these engines. On the Great Northern Railway (type *S*) the engines (990 class) are true "Atlantic" type engines, for they have the characteristics of the "Atlantic City" engines of the Philadelphia & Reading Railroad, in the United States, from which the type name is derived; that is, they have outside cylinders, the rear pair of coupled wheels are the drivers, and there is, of course, the proper wheel arrangement. On the Lancashire & Yorkshire Railway, the huge-boilered engines with this wheel arrangement have inside cylinders, and the front pair of coupled wheels are the drivers (type *T*.)

The writer has thus reviewed practically every locomotive type which has been in use to any considerable extent, or is still in use in Great Britain, according to wheel arrangement. Reference will now be made to the compound and multi-cylinder arrangements.

V. COMPOUND AND MULTI-CYLINDER TYPES

The compounding of locomotives has not received the attention in Great Britain that it has abroad. Nevertheless, the engines that we have are of great interest. Only on one railway have

LONDON & NORTH-WESTERN COMPOUND EXPRESS ENGINE. DREADNAUGHT CLASS. TYPE "C J." THE END OF THE LARGE INSIDE CYLINDER CAN BE PLAINLY SEEN

PHOTO BY J. LAKE

two-cylinder compound engines come into common use, though there are a few other such engines in existence. That railway is the North-Eastern, where the two-cylinder Worsdell-von-Borries system is employed. Types *CN*, *CO*, and *CB* have been used very extensively on this line; yet, such is the fate of so many compound engines in Great Britain, most of the passenger engines (types *CN* and *CO*) have been converted to non-compound engines, despite their previous good work, and only the goods engines are still all compound. The initial experiments were made by Mr. T. W. Worsdell on the Great Eastern Railway, and there also his compound engines of types *CO* and *CP* have long been converted to simple engines. The only remaining adherent appears to be an Irish railway, the Belfast & Northern Counties, and about those engines little is known. Such is the status of two-cylinder compounds in Great Britain, as gathered from the treatment they receive at the hands of our locomotive superintendents, who surely know their work, and that notwithstanding the fact that on the Continent compounds on the same and other two-cylinder systems are very favourably spoken of and are very numerous.

Our special and exclusive system of compounding is Mr. Webb's three-cylinder arrangement, in use extensively, but solely, on the London & North-Western Railway. Types *CJ* and *CM* indicate the wheel arrangements of the express engines constructed according to this system. From the cylinder diagram it will be seen that the front driving axle is driven by one large low-pressure inside cylinder, supplied from two high-pressure outside cylinders which drive the rear driving axle, the two pairs of driving wheels being uncoupled, so that the engine is virtually a "double-single." Type *CJ* is the more common, as the well known *Experiments*, *Dreadnaughts*, and *Teutonics*, with respectively 6-foot 9-inch, 6-foot 3-inch and 7-foot wheels, belong to it. Type *CM* is that of the long-boilered *Greater Britains* and *John Hicks*, with 7-foot and 6-foot 3-inch wheels, respectively. In the case of the London & North-Western three-cylin-

der goods engines, the three cylinders are all in line and drive onto one axle, and the eight wheels are coupled (type *CR*).

Another three-cylinder system has lately come into limited use, having one high-pressure cylinder inside and two low-pressure cylinders outside, all driving one axle which is coupled to another, the wheel arrangement being that of bogie type *O*. This is represented by the cylinder and wheel diagram marked *CO3*. On the North-Eastern Railway there is one engine thus compounded (Smith's system), and on the Midland Railway there are two.

We have now to consider the four-cylinder engines.

As compounds, the principal line employing them is again the London & North-Western Railway, and *CO4* and *CR4* are the types there in use, the first applying to the 7-foot coupled express engines and the second to the latest eight-coupled goods engines. The Lancashire & Yorkshire Railway is also experimenting with a four-cylinder engine of type *CO4*.

The London & South-Western Railway is also a user of four-cylinder engines, but in this case (type *U*) all the cylinders are high-pressure cylinders in two pairs, driving, respectively, the front and rear driving axles, which are uncoupled, as in the case of the London & North-Western three-cylinder compound engines. On the Glasgow & South-Western Railway there is an engine with four high-pressure cylinders driving one axle, type *O4*.

Mr. Ivatt has also just turned out from the Doncaster shops of the Great Northern Railway a new four-cylinder engine, not compound, of type *T4*, all four cylinders driving the front coupled axle, the wheel arrangement being according to type *T*.

There will also be in existence very shortly an engine having three cylinders, all high-pressure, and all driving on one axle, which will be the middle one of a ten-coupled engine. This description

SOUTH-EAST COAST RAILWAY EXPRESS ENGINE. TYPE "O." THESE ENGINES WERE ORIGINALLY DESIGNED FOR THE GREAT NORTH OF SCOTLAND RAILWAY, BUT WERE SOLD

PHOTO BY O. C. OWENS

applies to a new and unique tank engine now being built at the Stratford works of the Great Eastern Railway; but the particulars available are very vague and cannot be vouched for.

As regards the tank engines, these have been reviewed thoroughly in the May and September numbers of this magazine for this year, both as regards wheel and cylinder arrangements. Those two articles complete the writer's review of the locomotive types of Great Britain.

WATER-POWER IN ELECTRICAL SUPPLY

By Alton D. Adams

WATER - POWER is displacing steam - power in many systems of electrical supply, but there are divergent opinions as to the advantages of the change. A saving of fuel is most commonly assigned as the main reason for the adoption of water-power, but it is admitted that the steam plant must be retained in many cases, though its hours of operation are reduced.

In comparatively few systems is the available water-power sufficient to carry the entire load at all hours of the day and during all months of the year, so that the question of how much fuel can be saved is an undecided one for many plants. Again, the development of water-power often involves a large investment, and may bring a burden of fixed charges greater than the value of the fuel saved.

In spite of these conflicting opinions and factors, the application of water-power in electrical systems is now going on faster than ever before. If a saving of fuel, measured by the available flow of water during those hours when it can be devoted directly to electrical supply, were its only advantage, the number of cases where this power could be utilised at a profit would be relatively small. If, on the other hand, all of the water that passes down a stream could be made to do electrical work, and if the utilisation of this water had other advantages nearly or quite as great as the reduction of expense for coal, then many water-powers would await only development to bring profit to their owners.

No part of the problem is more unt certain than the first cost and subsequen fixed charges connected with the development of a water-power. To bring out the real conditions, the detailed facts as to one or more plants may be of greater value than mere general statements covering a wide range of cases.

On a certain small river the entire water privilege at a point where a fall of 14 feet could be made available was obtained several years ago. At this point a substantial stone and concrete dam was built, and also a stone and brick power house with concrete floor and steel truss roof. In this power house were installed electric generators of 800 kilowatts total capacity, direct connected to horizontal turbine wheels. The entire cost of the real estate necessary to secure the water-power privilege plus the cost of all the improvements was about $130,000 (£26,000). More than enough water-power to drive the 800 kilowatt generators at full load was estimated to be available, except at times of exceptionally low water. At this plant the investment for the water-power site, development, and complete equipment was thus $162 (£32.8.0) per kilowatt capacity of generators installed.

Allowing 65 days of low water, these generators of 800 kilowatts capacity

may be operated 300 days per year. If the running time averages twenty hours daily at full load, the energy delivered per year is 4,800,000 kilowatt hours. Ten per cent. of the total investment should be ample to cover interest and depreciation charges, and this amounts to $13,000 (£2600) yearly. It follows that the items of interest and depreciation on the original investment represent a charge of 0.27 cent (0.135d.) per kilowatt-hour on the assumed energy output at this plant. This energy is transmitted a few miles and used in the electrical supply system of a large city.

On another river the entire water privilege was secured about four years ago at a point where a fall of more than 20 feet between ledges of rock could be obtained and more than 2000 horse-power could be developed. At this point a masonry dam and brick power house were built, and horizontal turbine wheels were installed, direct connected to electric generators of 1500 kilowatts total capacity. The entire cost of real estate, water rights, dam, building, and equipment in this case was about $250,000 (£50,000).

Assuming, as before, that generators may be operated at full capacity for 20 hours per day during 300 days per year, the energy delivered by this plant amounts to 9,000,000 kilowatt-hours yearly. The allowance of 10 per cent. on the entire investment for interest and depreciation is represented by $25,000 (£5000) yearly in this case, or 0.28 cent (0.14d.) per kilowatt-hour of probable output. Energy from this plant is transmitted and used in a large system of electrical supply.

If, through lack of water or inability to store water or energy at times when it is not wanted, generators cannot be operated at full capacity during the average number of hours assumed above, the item of interest and depreciation per unit of delivered energy must be higher than that computed. With the possible figure for this item at less than three-tenths of a cent (0.15d.) per kilowatt-hour, there is opportunity for a large increase before it becomes prohibitive. At the plant last named the entire investment amounted to $166 (£33.4.0) per kilowatt capacity of connected generators, compared with $162 (£32.8.0) in the former case, and these figures may be taken as fairly representative for the development of water-power in a first-class manner on small rivers, under favourable conditions. In both of these instances the power houses are quite close to the dams. If long canals or pipe lines must be built to convey the water, the expense of development may be greatly increased.

One advantage of water over steam-power is the smaller cost of the building with the former for a given capacity of plant. The building for direct-connected electric generators, driven by water-wheels, is relatively small and simple. Space for fuel, boilers, economisers, feed-water heaters, condensers, steam piping, and pumps is not required where water-power is used. No chimney or apparatus for mechanical draught is needed.

The modern electric station operated by water-power usually consists of a single room with no basement under it. One such station has floor dimensions 27 by 52 feet, giving an area of 1404 square feet, and contains generators of 800 kilowatts capacity. This gives 1.75 square feet of floor space per kilowatt of generators. In this station there is ample room for all purposes, including erection or removal of machinery.

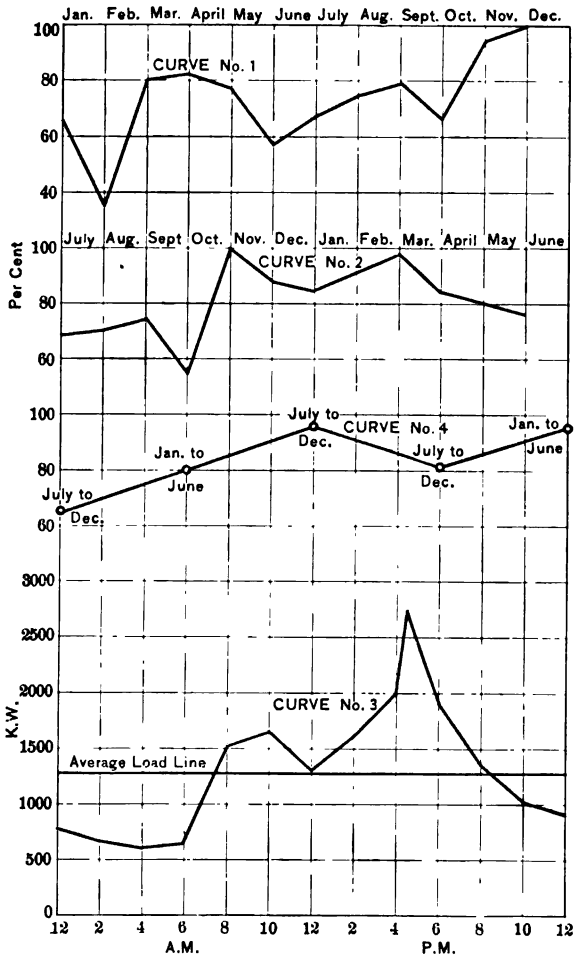
Next to the saving of fuel, the greatest advantage of water-power is due to the relatively small requirements for labour at generating stations where it is used. This is well illustrated by an example from actual practice. In a modern water-power station that contributes to electrical supply in a large city the generator capacity is 1200 kilowatts. All of the labour connected with the operation of this station during nearly twenty-four hours per day is done by two attendants working alternate shifts.

These attendants live close to the station in a house owned by the electric company, and receive $60 (£12) each per month in addition to house rent. Considering the location, $12 (£2.8.0)

per month is probably ample allowance for the value of rent. This brings the total expense of operation at this station for labour up to $132 (£26.8.0) per month, or $1584 (£316.1.0) per year, a sum corresponding to $1.32 (£0.5.3½ yearly per kilowatt of generator capacity.

At steam-power stations of about the above capacity, operating twenty-four hours daily, $6 (£1.4.0) is an approximate yearly cost of labour per kilowatt of generators in use. It thus appears that water-power plants may be operated at less than one-fourth of the labour expense necessary at steam stations per unit of capacity. On an average, the combined cost of fuel and labour at electric stations driven by steam-power is a little more than 76 per cent. of their total cost of operation. Of this total, labour represents about 28. and fuel about 48 per cent. Water power, by dispensing with fuel and with three-fourths of the labour charge, reduces the expense of operation at electric stations by fully 69 per cent.

But this great saving in the operating expenses of electric stations can be made only where water entirely displaces coal. If part water-power and part coal are used, the result depends on the proportion of each, and is obviously much affected by the variations of water-power capacity. In such a mixed system the saving effected by water-power must also depend on the extent to which its energy can be absorbed at all hours of the day. By far the greater number of electric stations using water-power are obliged also to employ steam during either some months in the year or some hours in the day, or both.



ENERGY CURVES FROM WATER POWER ELECTRIC STATIONS

It is highly important, therefore, to determine, as nearly as may be, the answers to three questions:—

First, what variations are to be expected in the capacity of a water-power during the several months of a year?

Second, if the daily flow of water is equal in capacity to the daily output of electrical energy, how far can the water-power be devoted to the development of that energy?

Third, with a water-power sufficient to carry all electrical loads at times of moderately high water, what percentage of the yearly output of energy in a general supply system can be derived from the water?

To the first of these ques-

tions experience alone can furnish an answer. Variations in the discharge of rivers during the different months of a year are very great. In a plant laid out with good engineering skill some provision will be made for the storage of water, and the capacity of generating equipment will correspond to some point between the highest and lowest rates of discharge.

Curve No. 1 in the diagram on the opposite page represents the energy output at an electric station driven entirely by water-power from a small stream during the twelve months of 1901, the entire flow of the stream being utilised. During December, 1901, the output of this station was 527,700 kilowatts, and was greater than that in any other month of the year. Taking this output as 100 per cent., the curve is platted to show the percentage attained by the delivered energy in each of the other months. At the lowest point on the curve, corresponding to the month of February, the output of energy was only slightly over 33 per cent. of that in December. During nine other months of the year the proportion of energy output to that in December was over 60 and in three months over 80 per cent. For the twelve months the average delivery of energy per month was 73.7 per cent. of that during December.

PERCENTAGES OF ENERGY DELIVERED IN DIFFERENT MONTHS, 1901

January	68.0	May	77.9	September	79.3
February	33.1	June	58.6	October	65.9
March	80.5	July	67.7	November	95.8
April	81.7	August	75.8	December	100.0

At a somewhat smaller water-power station on another river with a watershed less precipitous than that of the stream just considered, the following results were obtained during the twelve months ending June 30, 1900. For this plant the largest monthly output of energy was in November, and this output is taken at 100 per cent. The smallest delivery of energy was in October, when the percentage was 53.1 of the amount for November. In each of seven other months of the year the output of energy was above 80 per cent. of that in November. During March, April, May and June the water-power yielded all of the energy required in the electrical supply system with which it was connected, and could, no doubt, have done more work if necessary. For the twelve months the average delivery of energy per month was 80.6 per cent. of that in November, the month of greatest output.

PERCENTAGES OF ENERGY DELIVERED IN DIFFERENT MONTHS, 1899 AND 1900

July	68.6	November	100.0	March	98.5
August	69.1	December	87.0	April	85.7
September	73.3	January	84.9	May	80.8
October	53.1	February	91.3	June	74.9

The gentler slopes and better storage facilities of this second river show their effect in an average monthly delivery of energy 6.9 per cent. higher as to the output in the month when it was greatest than the like percentage for the water-power first considered. These two-water powers illustrate what can be done with only very moderate storage capacities on the rivers involved. At both stations much water escapes over the dams during several months of each year. With enough storage space to retain all waters of these rivers until wanted the energy outputs could be largely increased.

As may be seen by inspection of curve No. 2, the second water-power has smaller fluctuations of capacity, as well as a higher average percentage of the maximum output than the water-power illustrated by curve No. 1.

If the discharge of a stream during each twenty-four hours is just sufficient to develop the electrical energy required in a supply system during that time, the water may be made to do all of the electrical work in one of two ways. If the water-power has enough storage capacity behind it to hold the excess of water during some hours of the day, then it is only necessary to install enough water-wheels and electric generators to carry the maximum load. Should the storage capacity for water be lacking, or the equipment of generating apparatus be insufficient to work at the maximum rate demanded by the electrical system, then an electric storage battery must be employed if all of the water is to be utilised and made to do the electrical work.

The greatest fluctuations between

maximum and minimum daily loads at electric lighting stations usually occur in December and January. The extent of these fluctuations is illustrated by curve No. 3, which represents the total load on a large electrical supply system during a typical week-day of January, 1901. On this day the maximum load was 2720 and the minimum load 612 kilowatts, or 22.5 per cent. of the highest rate of output. During the day in question the total delivery of energy for the twenty-four hours was 30,249 kilowatt-hours, so that the average load per hour was 1260 kilowatts. This average is 46 per cent. of the maximum load.

Computation of the area included by curve No. 3 above the average load line of 1260 kilowatts shows that about 17.8 per cent. of the total output of energy for the day was delivered above the average load, that is, in addition to an output at average load. It further appears by inspection of this load curve that this delivery of energy above the average load line took place during 12.3 hours of the day, so that its average rate of delivery per hour was 438 kilowatts.

If a water-power competent to carry a load of 1260 kilowatts twenty-four hours per day be applied to the system illustrated by curve No. 3, then about 17.8 per cent. of the energy of the water for the entire day must be stored during 11.7 hours and liberated in the remaining 12.3 hours. This percentage of the total daily energy of the water amounts to 36 per cent. of its energy during the hours that storage takes place.

If all of the storage is done with water, the electric generators must be able to work at the rate of 2720 kilowatts, the maximum load. If all of the storage is done in electric batteries, the use of water may be uniform throughout the day, and the generator capacity must be enough above 1260 kilowatts to make up for losses in the batteries. Where batteries are employed the amount of water will also be somewhat greater than that necessary to operate the load directly with generators, because of the battery losses.

In spite of the large fluctuations of electrical loads throughout each twenty-four hours, it is thus comparatively easy to operate them with water-powers that are little, if any, above the requirements of the average loads.

Perhaps the most important question relating to the use of water-power in electrical supply is what percentage of the yearly output of energy can be derived from water where this power is sufficient to carry the entire load during a part of the year. With storage area for all surplus water in any season, the amount of work that could be done by a stream might be calculated directly from the records of its annual discharge of water. As such storage areas for surplus water have seldom, or never, been made available in connection with electrical systems, the best assurance as to the percentage of yearly output that may be derived from water-power is found in the experience of existing plants.

The question now to be considered differs materially from that involving merely the variations of water-power in the several months, or even the possible yearly output from water-power. The ratio of output from water-power to the total yearly output of an electrical system includes the result of load fluctuations in every twenty-four hours and the variable demands for electrical energy in different months, as well as changes in the amount of water-power available through the seasons.

In order to show the combined result of these three important factors curve No. 4 has been constructed. This indicates the percentages of total semi-yearly outputs of electrical energy derived from water-power in two supply systems. Each half year extends either from January to June, inclusive, or from July to December, inclusive, and thus covers a wet and dry season. Each half year also includes a period of maximum and one of minimum demand for electrical energy in lighting. The period of largest water supply usually nearly coincides with that of heaviest lighting load, but this is not always true.

Electrical systems have purposely been selected in which the water-power

in at least one month of each half year was nearly or quite sufficient to carry the entire electrical load. The percentage of energy from water-power to the total energy delivered by the system is presented for each of five half years. Three of the half years each run from July to December, and two extend from January to June, respectively. The half years that show percentages of 66.8, 80.2, and 95.6, respectively, for the relation of energy from water-power to the total electrical output relate to one system, and the half years that show percentages of 81.97 and 94.3 for the energy from water-power relate to another system.

For the half-year when 66.8 per cent. of the output of the electrical system was derived from water-power, the total output of the system was 3,966,026 kilowatt-hours. During the month of December in this half year more than 98 per cent. of the electrical energy delivered by the system was from water-power, though the average for the six months was only 66.8 per cent. from water.

In the following six months, from January to June, the electrical supply system delivered 4,161,754 kilowatt-hours, and of this amount the water-power furnished 80.2 per cent. For the six months just named, one month, May, saw 99 per cent. of all the delivered energy derived from water-power.

The same system during the next half year, from July to December, without any addition to its water-power development or equipment, got 95.6 per cent. of its entire energy output from water-power, and this output amounted to 4,415,945 kilowatt-hours. In one month of the half year just named only 0.2 per cent. of the output was generated with steam-power.

These three successive half years illustrate the fluctuations of the ratio between water-power outputs and the demands for energy on a single system of electrical supply. The percentage of 81.9 for energy derived from water-power during the half year from July to December represents the ratio of output from water to the total for an electrical supply system where water generated 94 per cent. of all the energy delivered in one month.

In the same system during the following six months, with exactly the same water-power equipment, the percentage of output from water-power was 94.3 of the total kilowatt-hours delivered by the system. This result was reached in spite of the fact that the total outputs of the system in the two half years were equal to within less than one percent.

The lesson from the record of these five half years is that comparatively large variations are to be expected in the percentage of energy developed by water-power to the total output of electrical supply systems in different half years. But, in spite of these variations, the portion of electrical loads that may be carried by water-power is sufficient to warrant its rapidly extending application to lighting and power in cities and towns

THE ENGINEER AS FINANCIER

By Dr. Robert H. Thurston

THE engineer's problem, in its most general form, is ultimately always a financial one, and may be concisely stated thus: — To provide for a prescribed result, in construction or production, in such manner as to make the investment one of maximum return. A more technical, but more specific, statement would be the following:—To make the ratio of value of the net ultimate returns to the capitalised net expenditure a maximum. This, again, may be paraphrased:—To make the commercial efficiency of the structure, apparatus, or machinery constructed, a maximum. This means, further, that the student of the problem seeks that solution which shall assure the largest possible continuous contribution to the returns on the investment represented by the complete enterprise of which it is an element.

To say that a certain machine is in maximum degree efficient, or that it has maximum efficiency, is, from this point of view, to assert that it will earn a maximum return on the capital invested in its construction, maintenance, and replacement. To state that a mill, a factory, an iron or a steel works, or a railway is in maximum degree successful from the engineer's proper standpoint, is to assert that it is capable of earning the highest possible dividends permitted by the conditions which influence its working.

Whatever the engineer may be called upon to do, he is finally judged successful or unsuccessful accordingly as the task undertaken by him more or less effectively contributes to the securing of a profit in the commercial operation in which his work finds place. It is always maximum financial result at minimum cost which is sought, and this is really the engineer's final problem in every case, however great or small the work.

Commercial efficiency and financial gain are measures of production of value by the expenditure of the unit of value. The purpose of seeking commercial efficiency is not the accumulation of actual money, but the provision of stored value which may be utilised in the acquirement of whatever desirable article or form of wealth may, at the time of such utilisation of that store of energy, seem likely to best meet the needs or the desires of its possessor. The whole business of the engineer, otherwise and broadly described, is the transfer and transformation of energies in such manner as to most effectively contribute to the wealth of the world in permanent and intrinsically valuable forms. He applies energy derived from a prime mover to the production of iron or steel, cotton or woolen cloths, and the product then represents stored energy in an amount which is always measurable in terms of money, as was the energy which produced it, either through transformation, as out of heat, or by transfer, as from a waterfall.

The product goes into the market and brings back to the maker its equivalent, as measured in such energy or in money, a portion of which energy is turned back into mechanism of production, and a portion, if a profit is made, remains in the form of potential energy, as capital, in the hands of the producer, to be used in extending his business, by enlarging production, or to be transferred into

other systems of manufacture or exchange. It is, however, just as absolutely stored and potential energy as is the latent heat of fuel, the stored energy of compressed air, or the content of the storage battery in electrical energy.

As there is a "mechanical equivalent" of heat and a "thermal equivalent" of dynamic energy, an electrochemical and a thermo-electric quantivalence, so there is, always and at all places, a precise equivalence of values between the financial representative of energy and the physical, and the price of a horse-power-hour is the measure of this quantivalence in money. A certain sum will, in a certain place and at a certain time, under defined conditions, in a fair exchange, buy a horse-power-year of, say, 3000 hours; or it will buy a horse capable of exerting a considerable fraction of a horse-power for a succession of years, it being necessary, however, to supply a certain other quantity of financial energy to provide food and shelter and care; or this sum will buy a definite quantity of stored energy in the form of coal which, in a steam engine, will, with the accessory expenditure of still other stored energy in provision of the means of realising its stored energy and applying it to its purpose, provide the power in the first instance directly purchased. The steam engine or the water-wheel through which transformation or transfer of energy takes place is itself a measure of value and is itself stored energy in a form which cannot be recovered, but which is capable of furnishing from Nature's stores other energy which will more than compensate that storage in this irrecoverable form and the final loss.

Money is not only the mechanism of exchange, but it is an element in that mechanism through the fundamental fact that, like fuel, like compressed air, like falling water, or like the chemical arrangement of the storage battery and its elements, it is a true potential energy storage system, its unit of energy capable of being exchanged, on definite terms at any stated time and place, for any other actual energy or any stored or potential energy. It is to be reckoned in the engineer's processes as energy, and is to be collected, stored, transferred, transformed, exchanged, precisely as other energies or representatives of energy, always with a view to gain by each step, each contributing more or less directly to the transformation of Nature's energies into permanent wealth, while, at the same time, contributing, in the process, to the pleasure, happiness, and comfort of mankind.

This fundamental problem of the engineer, as of every business man, may be shown to be invariably one involving that of maximum efficiency of utilisation of stored energy,—of capital. Capital is the stored energy of earlier workers, of generations of workers, often, which has been accumulated by ability and industry and through those devices peculiar to civilisation, and which, at the moment, constitute the twin pillars of industry,—money and credit. Its expenditure may be effected usefully and economically, or uselessly and wastefully, like thermal energy in heat-engines, and the engineer, as expert in its employment, is expected to see that its expenditure shall be made in maximum degree effective; in other words, effected with maximum efficiency. Commercial efficiency gauges the value of the thermal efficiency of the heat-engine, of the mechanical efficiency of all machines, and of the complicated and interwoven efficiencies of the railway, or of the whole system of national transportation and exchange, as well as of production.

The engineer is furnished with a certain amount of energy, actual or potential, in money or in credit, and is expected to utilise that potential energy in the production of machinery, apparatus, structures, or of systems of production, transportation and exchange of these crystallised forms of energy or of their product, portable wealth in the form of potential energy in food, stored energies in clothing, articles of comfort and of luxury or of necessity, and always in such manner that those who provide the initial store may secure a toll in financial energy from every transaction in which

they are enabled by the engineer to take part.

His task is thus the storage of potential energy in concrete form, in constructions of various kinds and of different materials, in each of which it will be permanently stored in definite amount. But in each of these products, if a machine, there will be incorporated, through the genius, the ability, and the industry of the engineer and his associates, a power of usefully transferring or transforming a current of energy, later to flow through it and its associated elements of the productive system of which it is to form a part, and in such manner that the expended and now permanently stored energy thus, in a sense, lost, shall be made good by still larger transformations out of storage, and energy potential in materials available for the purpose may be converted into useful, or, in some sense desirable, products, and, in this form, stored as potential energy once more.

It may thus be said that the problem of the engineer is the transformation and transfer of energies in such manner as to secure, ultimately, the conversion of the potential energy stored by Nature in the materials of commerce and engineering into potential energy in the form of manufactured products, in the meantime insuring the diversion of a certain part in that form of potential energy known as capital, or money. His whole business, professionally, is thus what may be in a sense denominated "applied energetics," and his professional success is measured by his ability to insure, in each operation, economical movements of energy with ample returns in stored energy of usefully potential form, a form known as capital.

He secures profit, and profit is potential energy in the form of capital. He secures this profit by transforming potential energy in the form of capital into other forms of energy, actual and potential, through a systematically arranged series of intermediate forms, until the outcome is the appearance of the full equivalent of the initial supply of energy in marketable forms of stored energy, together with an accession of energy, initially obtained from Nature's stores and rendered potential with the first, which "profit" is, in fact, representative of its equivalent value in brain-power, and in such quantity that it provides not only this profit, but also another installment of energy in financial form which permits compensation for that brain-power and all incidental costs of production outside these, appearing in the process of storing the physical work of the establishment, the intellectual work of its officers, and the genius of the inventors and the designers and the contrivers of methods of performance of work, of processes, and of organisations.

The energy-content of the annual product, in a successful business, must be the full equivalent, or more, of the financial energy invested, of the entire aggregate of physical, intellectual, and financial energy measurable at any one instant and at any one place in the process of production, and of the final outcome in capital resulting from disposal of the product in the market. Wherever this current of energy is sectioned in the course of its flow, the measure of total energy, actual and potential, in capital, labour, ability, and natural forms of energy illustrated in materials and in moving machinery and apparatus, and in acquired potential value of the article in process of manufacture, the aggregate energy, must be a constant or an increasing quantity. Thus the science of the engineer is a science of energy, and its gauge of value is, for him, always the money unit. Engineering from this point of view is finance, and finance is energetics.

The Problem of the Simple Machine may be taken in illustration of the principles and the practice which distinguish the operations of the skillful engineer, whatever his province or his special field of study and work. This problem takes this form:—

Required, the production of a specified article, in a stated quantity, at minimum cost in capital invested in the machine and in operative expenses, including interest, insurance, maintenance, repair, and replacement; the engineer

or designer or constructor to utilise the invested capital in the form of stored energy in the machine in such manner as to make the return sufficient to replace that capital in a reasonable time, with continuous transfer of natural energies in the required product, and final storage in such manner as to make the total measure of energy delivered, in the unit of time, such as will be the full equivalent of that supplied, plus an excess, from Nature's stores, as the measure of the advantage derived from the application of "ability" to this problem.

In common parlance, it is required to invent, design, construct and operate a machine in such manner that it shall produce, in the demanded amount, a certain product, and at a profit to the purchaser and user of the apparatus. It is reasonably well settled in advance that a profit is obtainable in the business, and it is for the engineer to make the ratio of returns to expenditures as greatly in excess of the usual contemporary profit as possible. If his machine cannot produce a profitable excess of stores of energy, he and his machine are alike failures; if he cannot secure a larger profit by his new construction than is usual with the old, he and his machine are, at least, not successes. The successful solution of the problem means a real and substantial advance upon current practice and a considerable increase of profits by the adoption of the new machine.

Commonly, by the expenditure of larger brain-power, of greater time, thought, and, usually, with increased expenditure of capital, the excess of gain over that secured by existing machines may be continuously increased as this introduction of added energy goes on; but the gain will have a decreasing rate. The judgment or the scientific computations of the engineer should determine, with substantial accuracy, where it will be wise to limit this accession of various energies in the production of the machine.

The problem of a simple machine sometimes must be studied, preliminarily, from one or another of two points of view, the purpose being, first, to ascertain whether it falls into one or the other of two distinct classes; secondly, to discover what are the constant and what the variable elements of the problem as it must be attacked by the designing or by the operating engineer. These two problems of maximum commercial or financial efficiency are liable to be confounded and sometimes appear to be identical; but they are actually distinct, and their solutions are in some instances as distinctly different and occasionally are very greatly different.

The Designer's Problem, as we will call the first, is enunciated thus:—

Given, the magnitude of the product to be provided for, in the unit of time, as the hour, the machine-cycle, or per annum. Required, such a construction as will furnish that quantity and quality of product at minimum total current expense. This means the apportionment of a machine, its type, design, size, and efficiency to a constant value of production, the variables of the problem being functions of size and cost of machine.

The Owner's Problem, as the second may be called, is the following:—

Given, the magnitude, the physical and financial and commercial conditions affecting the operations of a certain machine already working. Required, the quantity of the product to be demanded, where that quantity may vary, such that the return may have maximum value and give maximum profit.

Two controlling tendencies mark the improvement in the efficiency for commercial purposes of every product of the engineer's labour and their resultant varies as the one or the other is in the ascendant. These are increasing costs with increasing efficiencies, and advancing expenditures with diminishing gain. As the outgo for increments of efficiency and economy continues, the gain by increased efficiency is partly, or wholly, or more than wholly, compensated by the simultaneous increment of cost. With the crude apparatus of the earlier stages of uneconomical and incomplete industrial systems, there usually exist great opportunities for improvement by refinement of the appara-

tus and by systematising the industry at, often necessarily, increased cost in the form of invested capital.

Later, the possibility of further improvement lessens, and the costs to secure any given gain increase, until it ultimately becomes a fact that more must be paid for a given gain than it is worth, and the net outgo on the improved apparatus or system becomes, interest and sinking fund included, more than that on a less perfected machine or system. What may be called a "golden mean" is thus always found at that stage at which the cost of additional economies will exceed the necessary cost of securing them and where the result is loss rather than gain. The resultant of the two tendencies takes a direction which thus tends toward the unprofitable, and a limit may thus always be expected to be found, beyond which further refinement is financially undesirable. A steam boiler, a locomotive, or a residence for a poor man, may be improved by paying expenditures up to a certain point, beyond which further expenditure cannot profitably go.

The principle of converging lines of receipts and expenditures may be illustrated in many ways, but perhaps the most striking example is one in which we often find the point of convergence and overlap actually passed in practice. This is the case of friction and lubrication. In a system of mechanism, and especially in any extensive distribution and utilisation of mechanical energy, friction often is the great waste; in fact, friction is the only cause of waste of energy in transit between its point of origin at the prime mover and its point of useful, final application to its intended work. In some cases, as in the rolling mill or in the heaviest of machine tools, the waste by this reconversion of work into heat is comparatively small. In the steam engine of the Worthington type it is reported to have been in some cases less than 5 per cent.; but in lighter kinds of work, as in the cotton mill, and especially in the spinning department, and in all cases of transmission by shafting, the loss is serious, and is some times reported to be a very large percentage of the total generated at the steam engine or the hydraulic motor.

But a horse-power costs, even in the very best of mills, about ten dollars (£2) per year of 3000 working hours, and often, under less favourable conditions, this cost rises to twenty, thirty, or even fifty dollars (£4, £6, or £10); while the single horse-power is often sold, in the large cities, at the rate of one hundred dollars (£20). The lubricants are now commonly the mineral oils, with, as a rule, some admixture of animal or vegetable oil to give them body. The cost of the lubricant varies with its character from ten or fifteen cents (5 to 7½d.) a gallon for the less expensive varieties, to several times these figures for the finer and the fancy grades and for the high-temperature oils sold for steam cylinder lubrication.

The cost of the friction waste in any case is in but small part that of oils and lubrication; it is mainly that of the power wasted by the friction. The total cost consists of two quantities, therefore, and the sum of the value of the wasted power and the cost of the lubrication, including labour and materials and maintenance of the system and its operation, measures that total. But the relative quantities and costs of the two items vary with the efficiency of the lubrication, and while oil may be saved, as in one case reported, by using seventeen drops per twenty-four hours on a journal, just keeping it from heating, power will be lost and expense thus incurred of many times the amount saved by reduction of the cost of lubricant below a proper normal.

In the opposite case, the flooding of a journal with oil which is allowed to go to waste may reduce the wasted power to a minimum; but the cost of the oil in excess of that of wisely liberal and profitable supply may prove, on the whole, productive of a net loss. If, in any case, the supply of lubricant is gradually increased from the minimum safe amount to the maximum, and obviously wasteful, quantity, it will be found, on study of the variation of the two lines of expenditure and of saving, and of that of the total expense, that, as above indi-

cated, the cost of wasted power will at first rapidly and later slowly decrease to the minimum, as in heavy shafting, for example, from a coefficient of perhaps 10 or 15 per cent. to a fraction of 1 per cent.

The cost of the lubrication will steadily increase without limit inside that of a flooded journal, "bath lubrication," with which friction is but a small fraction of that observed with a comparatively dry and warm journal. The sum of the two costs, meantime, as steadily decreases until, passing a minimum at a comparatively low figure, it begins again to rise, and, after a time, rises in direct proportion to added costs of lubrication, with a constant and irreducible loss of power and its cost. An excess of oil then is wholly wasted.

The conditions of maximum efficiency of the unit of capital are closely studied by the capitalist, and the engineer, if he is to do his work properly, must consider himself bound by precisely the same considerations. If technically and actually successful as an engineer, his work must always result in the insuring of maximum efficiency of the capital supplied, and without reference to its source. He must always secure the desired result with such commercial success that any better or any worse apparatus or construction, of whatever kind, its quality being studied from the point of view of the mere constructor, that of abstract excellence, would fail to give equally large accessions to the dividend paid by the enterprise of which it constitutes a part.

There is a very obvious difference between the "duty," for example, of the most economical steam pumping engine and of that engine which insures maximum financial returns. The same designer, compelled to plan an engine for a guaranteed fuel or steam "duty" in one case and for maximum "duty of the dollar" in another, would produce a sensibly differently proportioned machine, and, in some cases, this difference would be most remarkable, as, for example, where in the one case the engine is to be erected where coal is very expensive, labour plentiful, first costs low, and maintenance and repair comparatively inexpensive, and where, in the other case, the machine is to be set up to drain a coal mine in the bituminous district, at a distance from the place of manufacture, in a time of high prices of construction, and where costs of maintenance and repair and replacement would be necessarily great.

In the one case a large and costly engine might be justifiable, while in the other the smallest and cheapest engine that can be provided will, perhaps, prove the best-paying investment. In this particular case it is easy, the conditions being exactly known, to approximately solve the Problem of the Golden Mean. In many cases, however, it is difficult, if not impossible, to solve it with accuracy.

The maximum returns on the unit of capital are frequently the result of a great number of widely differing and often conflicting conditions, and the insurance of the highest result, in such instances, evidently presupposes wisdom, judgment, experience, and special talent in exceptional degree. It is particularly important to secure this highest efficiency, in view of the fact that the adjustment, construction, and method of operation which is necessary to obtain it, is also usually that which insures the longest period of maximum returns and secures most permanently freedom from dangerous competition, with advancing improvement in the art constantly tending to bring later investments up to the momentarily established maximum efficiency, the new standard being still later excelled by newly introduced inventions and new discoveries and a more highly developed practice.

Because of this complexity of conditions in the common case of the operation of any great business enterprise and the constant flux and reflux of external, and often controlling, commercial conditions, it is very generally true that the most brilliant genius or the most learned expert may sometimes be quite at fault in the presence of the practical questions constantly arising, on the correct response to which success depends, and on the erroneous answer to which fol-

lows failure. It is wisdom and experience, rather than genius and learning, which here lead to safe and fruitful methods and insure the maximum returns.

In such cases it is often the safest, if not the only, way to judge the future by the past and to note the trend of a progress from earlier days up to and into the present, and from that trend to judge of the immediate future. It is only science which can to-day read an oracle of the future, and it is thus that the man of achievement avails himself of science, always the engineer's guide and leader.

Maximum commercial efficiency of an establishment, of a factory, a steel works, a workshop, or a mill implies maximum earning power, and a business enterprise of any sort will be successful in proportion as it earns good returns upon the capital invested in permanent construction plus capital tied up in that amount which would, if similarly profitable in another investment, produce the needed funds for operating expenses, including a sinking fund or maintenance account.

Such an assemblage of machines, tools or apparatus of production is itself, as a whole, to be regarded as one great machine, designed, constructed, and operated with a single purpose in view,—that of earning a profit on the invested capital. The problem, as placed before the engineer, usually takes the following form:—Required, the manufacture of a stated amount of a specified product annually, at minimum cost and maximum profit.

The factory is expected to be of such magnitude and construction that it may produce, say, 10,000 waggons per annum; the steel works is to produce a half-million tons of rails; the workshop must deliver a specified amount of tools and machinery; the mill, another specified amount of cotton or woolen cloth. The magnitude of the investment is known approximately, before the plans are drawn, through common experience in the business of the business men who promote it.

It is known also that at least fair dividends may be expected, and it is hoped that, by the introduction of all known recent standard and perfected devices, and inventions and methods, costs may be lowered and profits increased. The duty of the man who plans the establishment is to see that this expectation is fully justified. It should also be possible for him to anticipate with some accuracy what advance he will be able to insure.

The principles controlling the planning of a system of machinery are in this case to be extended to the establishment as a whole. It may be simply a mere aggregate of machines, or the problem may comprehend questions of location, of maximum economy in all relations of exchange affected by the character and length and cost of traversing the lines of supply of raw materials and of delivery of finished product, those of finding the best kind of labour, the most ample reserves, the best security against embarrassments arising from the ebb and flow of the markets for labour, for materials, for products, and for capital. It is the resultant of the interactions of all these conditions that must ultimately determine the adjustment for maximum financial efficiency of the total investment.

Here, as almost everywhere in the experience of the engineer and of the upbuilder of any commercial or manufacturing enterprise, it will generally be found that there are conflicting conditions, and that the insurance of the highest returns from one element of the system can be had only by sacrifice of returns on some other, and the line of the "golden mean" of compromise must be run, not only through this system of interdependent elements, but throughout the whole great organisation. It is this fact which makes so much depend upon experience and good judgment, on a clear, calculating brain, a sound common sense and a well-poised character, uniting courage and promptness of decision with a habit of fine analysis of those conditions which must determine the decision.

In general, the "plant" is to be located at that point on the lines of transportation between markets for raw material and those for finished product which will give, on the whole, the safest,

as well as the cheapest supply and delivery. The source of power, on the other hand, may be found, if the steam engine, for example, best located at a point where coal can be had from at least two different sources and at minimum cost, and this may be found to be the controlling element, the coal being one of the most important of the materials of supply and the product,—the power derived from it,—being delivered over lines comprehended within the limits of the works and transportable with them in locating.

As a rule, that location is best which, while maintaining independence by providing alternate lines for shipment, makes the sum of the distances over which transportation is carried on a minimum, or, more correctly, that which makes the aggregate of costs of all transportation charged against the business a minimum, and permanently so. This means that the future must be looked to, and careful consideration given to the outlook for later changes of costs and to the possibility of a monopoly securing opportunity to demand exorbitant rates.

These external conditions, affecting maximum returns, being settled satisfactorily, the problem resolves itself into that of the adjustment of its internal system to the requirements of maximum earning power of the capital invested and the working, the floating, capital and of all their incidentals. This commonly involves as the principal element a study of each machine, of each department, of each grand division of the organisation, to ascertain how it may be possible to make each individual in highest degree productive, or, more accurately, to make each capable of doing its assigned part of the work with maximum financial efficiency, delivering its output at the least cost, net, per unit, and at maximum net profit on that portion of the investment to be assigned that machine for its operation, its maintenance, and its replacement, or for the replacement of the capital sunk in its provision and its installation.

The labour question often requires more serious study than any other, and the insurance of an ample amount of skilled labour for the finer work, of unskilled labour for the coarser, of a satisfactory reserve for emergencies, of comparative safety against embarrassment by outside interference, will usually be found to demand most thoughtful and careful study. It is also possible that in any extensive enterprise, and especially in a mining or an iron or a steel-making organisation, the question of insurance of comfortable homes and of inexpensive living for the great mass of the employees will be recognised as one most closely affecting the ultimate prosperity and profitableness of the business. People of whatever rank or class will drift, in due time, and invariably, toward those points at which life promises most to them in comfort and pleasure and in security of employment. It is the character of the resultant of these social conditions which makes one place a centre of a dense population, another a desert, even though superficially appearing attractive. Gravitation toward the desirable is as natural and inevitable here as in the physical world, and affects people, industries, and nations inevitably; and capital as invariably tends to drift toward the same points of attraction.

Maximum commercial or financial efficiency of an organisation, as a railway, is attained precisely as with any machine and as with any industrial establishment. For a given production, which, in this case, is defined as a stated tonnage transported annually, the necessary labour and cost are made a minimum by good design, construction, and invention, while the unprofitable "burden" is cut down to its irreducible net minimum.

The roadbed must be so substantial that maintenance costs are minimised and that perfection is attained at which the sum of interest and the maintenance accounts shall be the least possible. The same principle applies to the buildings and stations, these being provided in such numbers and magnitude that each will be in maximum degree utilised and no capital wasted either in superfluous construction or in increased expense

on account of lack of proper accommodations. The rolling stock must be provided in that amount which will, on the whole, meet all demands without excess of stored capital, and of such quality that its maintenance may prove inexpensive and its net earning power great. Here, particularly, a well-made, substantial, and durable outfit is important, and the best in this sense is the cheapest. In the passenger department absolute comfort must be insured to give maximum returns, and a certain amount of luxury and extravagance will, on the trunk lines, at least, bring increased returns by attracting travellers. The experienced railroad man can usually make a close estimate of the value and the limits of this which is economically a waste, but financially a good investment.

The personnel is reduced to a minimum by careful systematisation, for wages and salaries count up rapidly and cut down dividends as seriously. Non-productive labour, as in the offices, is made the least practicable by skillful arrangement of work and a good system of reports and accounts. It often happens that, by a system which facilitates the work, by promoting the best possible book-keeping, the best, the most concise, and the clearest system of reports and records, the best methods of intercommunication between the superintendent or manager with and amongst the various departments, the force employed may be given greatly improved efficiency, as compared with the usual and average case, and thus a comparatively large business may be conducted with a minimised expense account.

In all this contriving it is to be remembered that the results of economies thus effected will prove far-reaching. The success of one enterprise will compel the competing lines to seek similar efficiencies, and the final outcome will be the improvement of the whole industrial system, with corresponding cheapening of costs of living, and, at the same time, as all experience shows, furnishing increased employment to ability and skill at better rates of compensation as the market is widened and as the demand is increased by the reduction of prices in the market generally.

The fact that the ultimate aim is the insurance of good dividends in all such cases is one which insures this constant study of all possible economies, the continual adjustment of compromises to give resultant gains, and the perpetual supervision of the whole organisation in all its details, seeking means of improvement of elementary and combined adjustments favouring lower rates and higher profits; for it is only when low costs and rates of transportation favour increased production, along the line of a road and throughout the country tapped by it, and when profits are thus shared with those who provide them, and so liberally as to encourage them to expand their enterprises, that maximum commercial efficiency and steady progress are assured either to the organisation or to its clients. It is thus that one railway may induce a great population to settle along its line, while a neighbouring and competing road may fail through its endeavour to " take all there is in it," in the adjustment of its tariff. Thus one great corporation may throttle a whole district and inconceivably retard its development, while another great enterprise may develop it and share its gains with everyone with whom it has dealings. The one policy is that of blind greed; the other is that of a wise and liberal selfishness. The one injures itself while abusing its privileges and imposing upon its neighbours; the other finds highest advantage, maximum commercial efficiency, to be insured by fairly dividing profits and advantages with its clients in the business.

An industrial system has maximum financial efficiency when, as a system, it produces a maximum value and quantity with a given use of capital, and when that product is so distributed as to give maximum returns to the people as a body. This, in fact, means distribution most widely and uniformly. An industrial system includes the whole productive and distributive apparatus and its organisations, having for its purpose the meeting of the demand of the country for a specified product and the supply

of the market in so far as domestic production meets the total demand.

An industrial system, in this sense, as, for example, the steel manufacture in the United States, is profitable to the country in proportion as it effectively employs its share of the labour of the country in ways which result in the production of the largest possible output per individual and per unit of capital employed. The two latter are related conditions; the maximum product *per capita* and maximum production per unit of capital go together, both being attained by utilisation of invention and of labour-assisting machinery. Maximum production *per capita* and per unit of capital is insured by making the immediately productive operations in maximum degree efficient, and, at the same time, reducing the other classes of labour and cost to a minimum.

The insurance of constant employment of the labour engaged in that occupation with maximum productivity of each individual is secured by his steady work with highest skill throughout the most suitable working day, by the employment of machinery for every task which can be assigned it, by the making of man and machine in highest degree fruitful of profit, making each capable of doing a large amount of fine work, by the minimising of costs of raw material and of marketing finished product, by avoidance, throughout the system, of labour which does not contribute to economical production. These are the principal methods of insuring maximum financial efficiency of an industrial system and maximum returns to the people, as well as to investors.

The industrial system, employing the terms in the restricted sense above implied, the system of production of a specified article or a defined class of products, is necessarily dependent for its prosperity not only upon its own economical and profitable organisation and administration, but also upon the exterior conditions of the country at large. It is in maximum degree efficient as a system of profitable use of capital when it is best interacting with the whole industrial system of the country and that with the world. It is one element of a greater system and of a vastly larger organisation, and all must stand or fall together; all will share either prosperity or disaster. That union of internal efficiency with external accommodation to the social and economical and financial conditions of a country which best promotes mutual interests and mutual convenience and the sharing of advantages and of fair profits amongst all, and with the people generally, will insure the best balance sheets in the long run and will be most certain of permanent and satisfactory returns.

The industrial system will exhibit maximum commercial and financial results when it most completely meets the needs of the time with maximum production of the products of manufacture, minimum labour applied to agriculture, the shortest working day consistent with provision of the whole people with a satisfactory supply of the necessaries and comforts of life, and a reasonable amount of reasonable luxuries, sharing its output fairly in proportion to the earnings of its individual workers above a proper minimum.

Maximum efficiency of a nation, industrially and commercially, is subject to certain imperative conditions, making the required form of the system a matter other than that immediately satisfactory economically. The laws of insurance come in to complicate the problem, which is now that of the statesman as well as of the engineer.

Every nation must, first of all, be made in maximum degree safe against foreign aggression. This means not simply that it must have a reliable army and a sufficiently large and powerful navy, but also that it shall be as independent, if possible, industrially as it is politically. It is a matter of primary importance that, should it happen that the nation is shut up within its own boundaries by an enemy, it may continue to go on, without embarrassment, providing for its own essential needs through its own industrial system precisely as if at peace. This principle defines the extent of that industrial system and compels the support of all industries

that may be in any sense considered essential and fundamental; it gives form and limit to the industrial system as a whole.

This maintenance of industrial independence is obviously no less important as a part of the duty of the statesman and the legislator than that of providing and maintaining an efficient and sufficient army and navy. In fact, the army and navy of a nation at war with a powerful enemy are helpless for defence if, meantime, dependence upon outside markets of supply deprives the country of the essentials of life. The dependence of Great Britain, for example, upon other nations for food constitutes an enormously serious danger and compels the maintenance of a navy as enormously in excess of that which would otherwise be necessary, in order that the paths of transportation to America and Australia may be held open in war-time.

The industrial independence of the nation being assured as giving a certain degree of safety against any possible hostile actions of a foreign foe, martial or industrial, the next element to be considered by the legislator and the statesman, as well as by the leaders of the industrial army, is provision for the exchange with other peoples of products which may be made most cheaply by each in its own country and under the particularly favourable circumstances there existing. This commonly means exchanges between the temperate and tropical zones, meridianal rather than along the parallels of latitude; but it may mean exchanges between undeveloped and highly developed countries, between countries having deficient and those having liberal supplies of raw materials and those natural resources which are essentials of civilisation and progress.

Another essential of the prosperity, progress and maximum commercial efficiency of a nation is the diversification of its industries. As it rises in the scale of civilisation, its wants become more numerous, it shares more and more in the productions of all climes and all peoples, it produces a larger and larger proportion of intelligent and highly skilled workers, and it demands more and more opportunity to supply fine work to fine mechanics and artistic classes at correspondingly increasing compensation for their skill, their talent and their genius. As the development of the fundamental industries to the highest possible state of commercial efficiency is the gauge of progress in comfort and general distribution of the fundamentally essential elements of wealth, so the diversification of industries by the introduction and extension of the finer sorts of production is a gauge of the progress of the people toward higher ideals and in power of securing those healthful luxuries which are the finest measure of spiritual advancement. As, also, the production by a people of its essential products, the necessaries of life, becomes more and more possible in a restricted working day, and as time is thus gained for higher work and for employments of a finer sort, the energies of the art workers must be thus provided profitable application, and the larger the proportion of this elevated and æsthetic work, the higher and the nobler, other things being equal, will be the life of the nation.

When the taste of a nation has thus become cultivated, its morals, its manners, and its culture all take on higher forms, and, in time, modern nations should acquire, as peoples rather than simply in their aristocratic or wealthy classes, that general intelligence, cultivation, and elevated character which have been the ideal of every great mind from the times of Plato and Socrates to those of Milton, Carlyle, and Emerson.

Meantime, the whole people must be permitted to participate in production, and each according to his or her talent, skill or genius. The whole available energy of a nation, reinforced by all the physical power that its resources permit it to draw from the great sources of energy in Nature, must be as completely and as continuously as possible employed, and each individual and each machine and every organisation at maximum commercial efficiency. Thus the whole nation should become itself a mighty apparatus of maximum efficiency in the work of supplying all the neces-

saries and as many of the comforts of life as possible to its people, and a fair share of luxuries of wholesome and desirable sorts to as many as may earn them, and, finally, with the most complete distribution possible.

Maximum efficiency of a nation is thus attained when each citizen is kept industriously and continuously at work throughout the best working day period, producing his best and highest product, when this highest product gives the nation the largest proportion of permanent wealth of æsthetic forms, such as its people can best enjoy, and of most generally distributed comforts of highest civilisation. Maximum efficiency of a nation means, further, the provision to its people, generally and with uniformity of distribution, of leisure and opportunity for that cultivation of the finer arts and vocations now restricted to the "leisure classes." It is for this ultimate purpose, ethically, in fact, that the whole industrial system should be organised.

The ultimate purpose, the economic and social problem, of the industrial system and its upbuilder, the engineer of whatever sort, is now readily recognised and defined. It is the maintenance of the population of the nation in a state of maximum productivity. This being insured, the progress of the nation in wealth accumulation, in opportunity for profitable and satisfying life, for improvement in manners, morals, and culture, the real purposes of existence, in mutual service, in perfecting humanity, will become the greatest possible, and a modern world will approximate highest efficiency in the production of Man.

Having insured political independence and safety against embarrassment by antagonistic peoples or interests; having secured equally complete industrial independence in the sense of ability to produce, if compelled, every article which may be needed by the people in case of isolation by war or pestilence or industrial changes; having acquired, in the most extended degree possible, diversification of industries and the utilisation of all workers, each in his highest field, with as complete utilisation of all available natural energies, the way is clear for unimpeded advance toward the highest perfection of the individual. Except for this ultimate aim and final result of progress it would have little worth.

Every step in this triumphal progress of the arts and sciences and of a material civilisation, advances made in the financial improvement of method and of result, all advances in profitable employment of labour, of skill, of ability, and of capital, and each successful solution of the problem of maximum financial efficiency and maximum commercial returns,—each and all—conspire toward the same end. Haeckel, the monist, and Shaler, the Christian philosopher, —the two extremes of opinion and of tendency,—agree in this.

This problem being solved, this purpose being attained, the work of the world is performed with the highest commercial efficiency, the production is in largest degree that of permanent forms of wealth, this wealth is the output in largest possible proportion, presumably mainly of machinery, and the people are competent to produce all that is desired in a short working day, and the product of the labour and of the brain of the nation is, in maximum possible degree, uniformly distributed. In the attainment of this end the engineer and his comrades in the industrial army find opportunity to utilise industry, talent, knowledge, and fruitful experience; and the clue to highest efficiency in every direction is that of successful finance in productive enterprises of a legitimate sort in every part of the industrial system.

Maximum efficiency of man, approximation to the ideal, perfection of the real, uniting the "soul of the sage with the body of the athlete," can be attained only by a body of people, by a race, when the industrial system is brought to its maximum efficiency both in productiveness and in quality and character of product. When the industrial system is so efficient that the people can produce all that they desire of all really desirable things and can yet have ample leisure for thought and culture of mind

and body; when wise employment of mind and body finally, by however long a period of evolution, give the race that perfection, individually and collectively, that it is easy to see is possible, with noble mind in noble body, the highest exemplification of efficiency, of maximum financial and commercial efficiency in the highest sense, will be seen.

Man thus becomes capable of highest efficiency in the production of his highest products. He is intended to produce, ultimately, a spiritual output through a succession of changes, which, in series, give complete satisfaction to his physical needs, and to length of life at highest practicable rate of production; to his æsthetic nature, to his intellectual ambitions, to his moral nature, to his spiritual self, and, finally, with maximum output of a maximum proportion of highest intellectual and spiritual life, individually and as a people. The maximum efficiency of man is attained when not only he illustrates the combination of the most perfect body with the most perfect soul, but when body and soul are, in their turn, in maximum degree productive in their highest forms of sane activity. The commercial aspect of the industrial system is an essential factor of intellectual, moral and spiritual growth of the individual and of the race.

Man, individually, is of maximum efficiency, both ideally and actually, if he is producing continuously his highest and best product. Man, collectively, is in maximum degree contributing to the best interests of the world when each man is producing a maximum annual product of that sort which he is best fitted to contribute, when all are industriously productive through a maximum working life, when the largest proportion are engaged in increasing the permanent wealth of the world and when the minimum amount of time and thought and labour is given to the production of the perishable and of the wastes of civilisation. Science, literature, the useful arts, the fine arts, then flourish in proportion to the skill, talent, genius of the people, and manufactures afford employment in maximum degree, agriculture in minimum degree, consistent with the needs of the whole people. Cities give opportunity for the active and the productive; the country adjacent provides homes for the leisure class and the brain workers by vocation. The one lends itself to the useful; the other, to the fine arts. Transportation from the one to the other becomes daily more easy and more prompt. The interspersion of city and country, manufactures and agriculture, the proximity of seats of learning to locations where manufacturing abounds, of the æsthetic to the useful, of artists and authors to artisans and exchangers of products and of capital, gives maximum mean efficiency of the whole body politic.

The engineer's noblest task is thus to be finally accomplished and his greatest problem solved by the reduction of all industrial systems and their details to a perfection which is defined as that of maximum financial efficiency. But this definition, which savours of the world of "commercialism," is really but the scientific statement of the fact that it is by the development of the industrial system that we are to enable the people to become better and more intelligent, wiser and more cultured and more just, that the progress of the nation and of the race is to be assured. Maximum financial efficiency means maximum wealth; maximum wealth means maximum opportunity; maximum opportunity means that the people will constantly more and more follow their noblest aspirations and steadily gain in spiritual, moral, intellectual, physical, and even conventional ways. The engineer, as financier and as the builder of the modern industrial system, is the essential pioneer in the mission work of the coming civilisation.

Great as has been the progress of the last century, the one century of industrial organisation and real progress, we are still not so far removed from barbarism,—as witness the hysterias, the "fads," the outbreaks of savagery of every nation,—and we have a long way to go in the endeavour to reach our ideal. In the van of this progress, and all along the lengthening way, the engineer and his comrades are pioneers,

and must necessarily lead the way and point out the path. It is only along a road built on substantialities that civilisation may advance.

Greece speculated and—stood still. America, with its industrial, peaceful rivals, invents, produces, thinks, works, and ignores hypothesis; it advances farther and faster and with a more rapid and constant acceleration than Greek or Roman, or than Solomon, or Aristotle, or any prophet or seer of the Middle Ages ever in his wildest dreams conceived possible. It is by the work of the worker, not of the dreamer, by production, not by speculation, that the nation, the race, the world will advance toward the ideal life and its ideals of man.

It is for the engineer, not only as financier, but as leader in industry, in finance, in applied economics, and in statecraft, as the man who is expert in the arts, in the finance, the organisation, and administration of the system of production, to insure the safe and efficient operation of all for which government itself is organised. It is the engineer who must assume the largest responsibility and who has the largest opportunity in this promotion of the best interests of mankind.

A CONSTRUCTION VIEW OF THE INTAKE

POWER FROM LAKE SUPERIOR

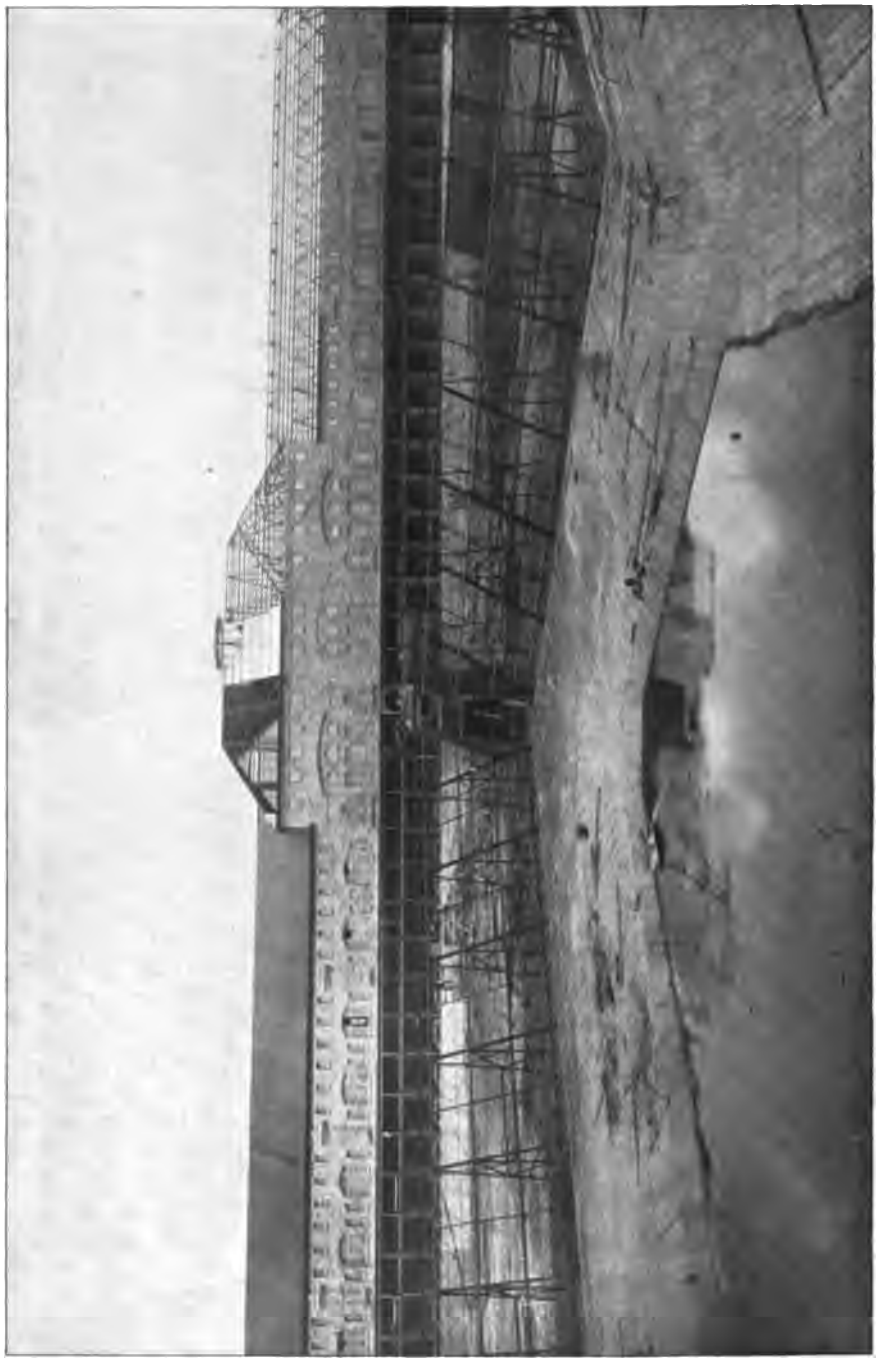
ELECTRICITY FROM THE RAPIDS AT SAULT STE. MARIE, MICHIGAN, U. S. A.

By H. Von Schön, Chief Engineer of the Michigan Lake Superior Power Company

THE mammoth hydraulic power plant which was in course of construction during the last four years at Sault Ste. Marie, Michigan, U. S. A., was completed last summer. During the past few months the canal and power house, and every part of these structures which become subject to strains of hydraulic heads during operation, have been tested by filling and unwatering to different elevations, and finally on October 25, which was the fourth anniversary of the day on which the contracts for construction were executed, the Consolidated Lake Superior Company invited the people of the twin cities of Sault Ste. Marie and numerous friends from the different States and the Dominion of Canada to join them in celebrating the actual opening of their works.

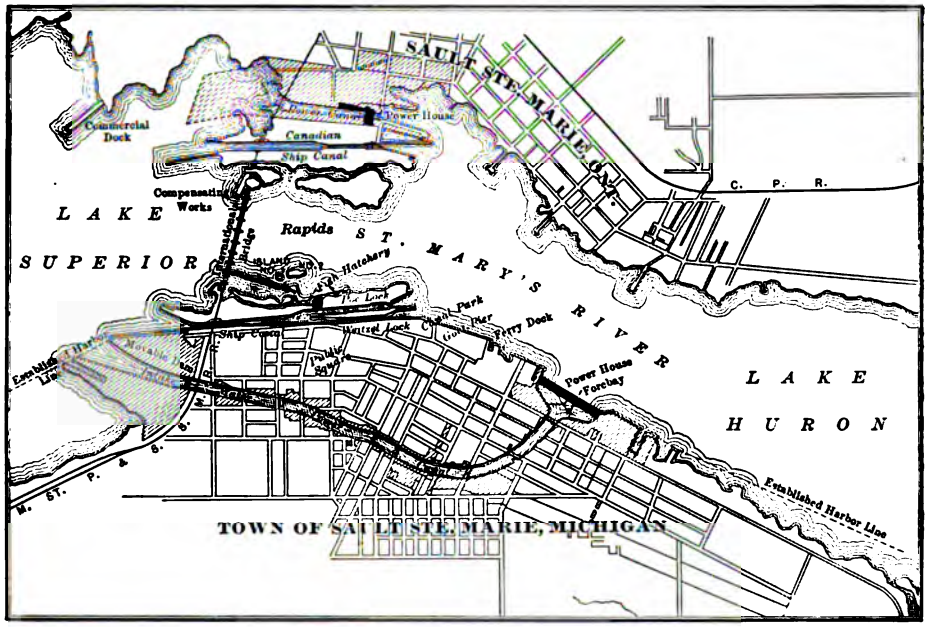
The celebration, in keeping with the scope of all the undertakings of the great enterprise, was started on October 23 by an entertainment given on the part of the company to about two hundred citizens, composed of the different committees who arranged for, and prepared to carry out, the different features of the celebration programme. On October 24 all the children of the community were entertained by the company, being assembled at the High School of the city, and marching, after there being addressed, through the city to the big power house, where the company served a collation, and entertained them with music, sports, and games.

THE POWER HOUSE AS SEEN FROM THE RIVER



THE FOREBAY GRADUALLY EXPANDS, AS HERE SHOWN, TO A WIDTH OF 1400 FEET. THE INTERCEPTING RACK AND SPILLWAY CHUTE CAN BE SEEN IN THE FOREGROUND

October 25, the day proper of the opening ceremonials, was ushered in by such a combination of joyful noises that not a man, woman or child within several miles of the neighbourhood of the Soo Rapids could remain in ignorance of the meaning of the day after sunrise. A most excellently organised civic parade, in which about six thousand men marched, arrived at the power house at about noon, where, at a stand, erected for the purpose and handsomely decorated, Miss Helen Clergue, sister



MAP OF THE SAULT RAPIDS, SHOWING THE POWER CANAL AND THE LOCATION OF THE POWER HOUSE

of F. H. Clergue, the genius of the enterprise, opened the works by turning a small jeweled switch which threw open the first set of turbines operated for the purpose of delivering power and carrying current of a 500 horse-power dynamo to strings of arc and incandescent lamps and to a handsome street car, the first to run over the tracks recently laid down by the same company in the two cities along the shores of the rapids.

It was a spectacular performance, accompanied by the booming of cannon, the tolling of bells, and the passing up and down the river in front of the power house of an impressive fleet of vessels. An historical and industrial parade composed of eighty different floats, headed by a cavalcade of Indians and voyageurs and of all the old-timers of the American northern countries, made its way through the gaily decorated streets of the city, the day being brought to a close by a large banquet tendered by the Consolidated Lake Superior Company to about four hundred guests, and by a torchlight parade and illumination of the quarter-of-a-mile-long power house and the seven bridges crossing the canal.

On Sunday, October 26, a thanksgiving service of all the people of the two cities was held in the power house, thus concluding the continuous three days' celebration of the event.

In the water-power development at Sault Ste. Marie has been realised the utilisation of the natural force inherent in the waters of Lake Superior as they flow over a sandstone rock ledge about half a mile long, half a mile wide, with a fall of 20 feet.

Lake Superior covers an area of

THERE ARE EIGHTY-ONE POWER UNITS, EACH CONSISTING OF FOUR 33-INCH TURBINES, CASED IN PAIRS, TANDEM FASHION, DROWNED WHEN OPERATING. EACH UNIT IS CAPABLE OF DEVELOPING 568 H. P.

about 30,000 square miles, and the Sault rapids are its only outlet. The quantity discharged fluctuates with the varying conditions of precipitation and evaporation from about 3,600,000 to 7,000,000 cubic feet per minute, which, rushing over the Sault rapids, represents an equivalent of from 130,000 to 260,000 horse-power.

This Sault Ste. Marie has enlisted the efforts of men from the earliest settlement of the countries about the Great American Lakes, not only with a view of harnessing its dormant power, but overcoming its obstruction to navigation from Lake Superior into Lake Huron. Water-power developments for various purposes and of different scopes have been planned, attempted and carried out, and locks by which boats have been enabled to pass these falls have been constructed and operated during the past one hundred years; but it has been left to this day and generation to witness the practical consummation of the greatest possibilities in both directions, since of this formerly dormant power more than half has now been brought under control, while locks are now in operation capable of passing up and down the largest fleet of merchant carrying vessels on the face of the globe.

It is not the purpose of this article to enter into what would be a very interesting general history and description of the gradual development of water-power and navigation facilities at Sault Ste. Marie, but rather to deal with the water-power development just completed which has attracted so much attention because of its gigantic scope and the engineering and mechanical features which have been incorporated in it.

The Michigan Lake Superior Power Company is the corporation which has successfully carried through this great work, and Mr. Francis H. Clergue, the president and acting manager, is to be credited with its conception and successful realisation.

This company, coming on the scene in 1894, and finding the wreckage of a former attempt in the shape of mortgages on real estate and right of way held by a local bank, secured them and became the owner of the charter rights and property formerly owned by the St. Mary's Falls Water-power Company in 1885-6-7. Investigating and planning were carried on during the succeeding two years, the general programme contemplating the development of about 60,000 horse-power by taking the water from the foot of Lake Superior above the Sault rapids, carrying it by a sufficient canal through the city of Sault Ste. Marie, Michigan,—six iron foot and vehicle bridges spanning the canal in this distance,—to the nearest available point below the rapids, and there discharging it into the St. Mary's River by letting it pass through a power house containing the necessary hydraulic apparatus, to transform, by so falling, its inherent kinetic energy into mechanical power, which, being available at the turbine shaft, was to be transformed into electrical energy by driving generators.

Tenders for the construction of the works were called for in the summer of 1898, and contracts were awarded in October, 1898, to Messrs. H. W. Hubbell & Co., of West Bay City, Mich., for the construction of the intake; to Messrs. E. D. Smith Co., of Philadelphia, for the building of the canal proper; and to Messrs. Mason & Hoge Company, of Frankfort, Ky., for the construction of the forebay and power house. Construction was entered upon all these works shortly after the letting of the contracts and was carried on continuously up to their completion.

As finally contracted for and completed, the works differ only in structural details from the original conception, and may be generally described as follows:—Just south of the western entrance to the United States ship canal lies the intake to the power canal, 950 feet wide, its southern alignment running nearly east and west from its intersection with the established harbour line on a tangent for about 2900 feet, while its northern boundary, commencing at its junction with the terminal of the ship canal pier, trends southeasterly, gradually curving in towards the south line and narrowing from 950 feet at the beginning to a width of 250 feet at a distance of 1000 feet from

A VIEW OF THE CANAL WHERE IT PASSES FROM ROCK INTO EARTH

the point where the waters of Lake Superior enter, and thence continuing at this width to the eastern end of the intake, where it terminates in the head gates of the canal, also called the "movable dam," being a structure designed to close off the flow of water from the canal under all possible conditions.

It, therefore, forms the entrance to the canal proper, which, from this point till terminating at the forebay, is about 9000 feet long, runs generally easterly for 6000 feet, then gradually curving northerly for the remaining 3000 feet, when it again expands into a forebay, having the character of a mill pond, being closed by a dam which has been elaborated into a power house, falling through which for a distance of 20 feet, the water coming down through the intake, canal, and forebay, finds its final exit into the tail race, St. Mary's River or Lake Huron level.

The total length of the constructed waterway, therefore, is about 13,000 feet, the width from the expanded intake entrance becoming gradually 200 feet, excavated to such a level that when the full scope of the power for which the works are erected is being used, water will flow in the canal at a uniform depth of 23 feet. Reference to the map on page 349 will prove of interest here.

The waterway crosses a variety of material, first entering the intake and passing through drift of Lake Superior sand, boulders, and gravel for about 1500 feet; through about 4000 feet of the rock strata which traverse this region and are responsible for the existence of the rapids; thence again into the formation of drift sand and boulders for 3000 feet; finally entering a formation of silicious clay through which it flows to the terminal,—the power house.

The entire construction of the canal was carried on with a view to render it of the greatest efficiency as regards its possibilities of delivering the kinetic energy of the water, and everlasting in shape and durability. Throughout the intake the sides of the canal are retained by timber cribs, securely placed and framed, making the sides of the waterway smooth and permanent. The timber construction is continued to just below water and is topped off with masonry construction.

The canal sides through the rock formation are channelled out vertically, its walls and bed being smooth, all defects in stratification being remedied by mas-

onry construction, of which the embankments also consist. Passing on through the sand, the prism of the canal becomes trapezoidal, with slopes of 1 in 1, its width at the bottom being 164 feet and at the top, about 214 feet. When entering the clay formation, the trapezoidal prism is gradually converted into an elliptical or compound trapezoidal prism, the sides consisting of three different slopes,—the top 1 in 1, the centre 4 in 1, and the last 10 in 1,—this form of the canal prism expanding into the forebay, the slopes of the latter again becoming 1 in 1. The prism of the canal where it traverses sand and clay is secured by timber revêtement, which consists of log sills placed across the entire prism, slopes, and bed every five feet, being secured to piles driven into the bed and slopes, the spaces between them filled with puddling material, and the surface covered with heavy timber planking, thus reserving the shape of the prism and reducing to a minimum the loss of the kinetic energy of the water while flowing along the sides and bottom. All timber in the canal construction terminates below flowing water level, the banks above water consisting of stone pavement resting upon and against the timber bulkhead at a slope of 1 in 1. Every portion of the conduit, therefore, except the beds of the intake and forebay, is formed either of smooth rock or timber surface, so constructed as to preserve the original shape of the conduit and exposing only stone to the wearing influence of the elements.

FOUR STEEL SHUTTERS,—STONY SLUICES,—EACH 48 FEET WIDE AND 26 FEET HIGH, OPERATING BETWEEN MASONRY PIERS, CONSTITUTE THE CANAL HEAD GATES AND CONTROL THE FLOW OF WATER TO THE POWER HOUSE

The flow area of the canal differs with its different sections, being in the intake 4800, in the rock channel 4600, and in the sand 4300 square feet. The water will flow 23 feet deep through the entire canal, and when the full plant is running, the velocity of the flow will be about four and a half miles an hour, which would deliver approximately 30,000 cubic feet of water per second to the turbines, realising under the flow which will remain available after making proper deductions for loss while the

water is carried throughout the conduit, about 60,000 horse-power. The conduit terminates, as already stated, at the power house, which performs the function of a dam in which water-wheels are so placed that the only escape for the water to the lower level is through them.

The foundation of the power house is of the pile-bearing type, about 12,000 fifty-foot piles having been driven through the clay to the rock, their tops capped and filled with a mass of concrete 3 feet deep. The substructure, or pits, whose purpose it is to carry the water into the river below after passing through the turbines, consists of eighty-one chambers, 100 feet long and 20 feet high, separated from one another by 3-foot masonry walls, the floors and roofs being monolithic concrete arches closed on the up-stream side by masonry concrete arches.

The penstock structure resting upon this pit structure consists also of eighty-one chambers opening on the up-stream side, each 15 feet wide, 45 feet long, and 20 feet high, divided from one another by steel and concrete constructions, closed on the down stream side by semi-circular steel-plate bulkheads, open on top. These chambers contain the water-wheels, the water received from the forebay standing in them to their full height and falling through the water-wheels into the pit below.

The down-stream portion of the substructure not occupied by these penstocks is available for the dynamos. Upon this structure, supported by steel columns and steel floors, rises the upper portion of the power house, consisting of two additional floors, 15 feet wide and 1368 feet long. The walls of the house are of sandstone, excavated from the canal; the roof frame is of steel; and the covering is of galvanised corrugated iron.

Each hydraulic unit is composed of four 33-inch turbines, arranged in two pairs on one shaft, each pair being housed in one case and discharging into one draught tube. The installation is of the horizontal, tandem type, the shaft and operating rigging penetrating the steel-plate bulkhead and coming out on the dynamo-floor side. Each hydraulic unit under normal conditions, to wit, taking 391 cubic feet of water per second at an effective head of 16 feet, equals 568 H. P., their efficiency varying from 81 per cent. to 82 per cent., as ascertained by actual tests prior to their acceptance. The electric units consist of 400 KW alternating and direct-current generators, made by the Westinghouse Electric & Manufacturing Company, of Pittsburgh, Pa., and the Stanley Electric Manufacturing Company, of Pittsfield, Mass., U. S. A.

The material involved in the construction of these works consisted of 1,250,000 cubic yards of rock and 3,000,000 cubic yards of sand excavated and dredged, the material all being utilised in reclaiming lands under water, the property of the operating company; 3,500,000 lineal feet of piles driven, 170,000 cubic yards of concrete and monolithic blocks, 90,000 cubic yards of sandstone masonry, 32,000 square yards of dry sandstone pavement, 360,000 barrels of cement used in all masonry, and 24,000 square feet of iron roofing.

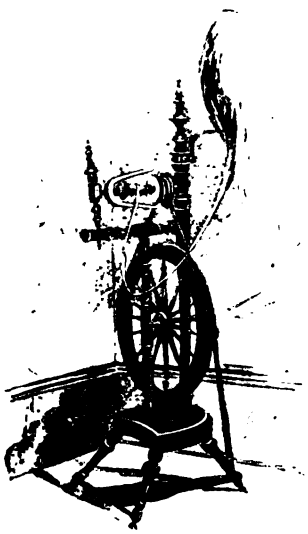
Two hundred and sixty acres of land were reclaimed during the construction, being filled in with the excavated material, 2800 lineal feet of navigation docks were built, and 22 miles of railway were laid and operated. The excavation was carried on with an equipment of 8 steam shovels, 24 locomotives, 350 four-yard dump cars, and the work was carried on day and night, excepting Sundays.

The approximate cost of the entire right of way, canal, power house, equipment, docks, and appurtenant works is about $4,000,000 (£800,000). The total amount of power developed at lowest conditions will be about 57,000 horse-power.

LUBRICATION OF TEXTILE MILLS

By William F. Parish, Jr.

The facts outlined in the following paper, originally presented at a recent meeting of the New England Cotton Manufacturers' Association, and specially revised by the author for republication here, were obtained from a large number of comparative tests made under a new system of testing. They add a good deal of valuable practical information to the available data on the subject in question.—THE EDITOR.



DURING the last ten years much has been written upon the subject of lubrication from a theoretical standpoint, and many tables have been prepared showing coefficients of friction determined by using various lubricating materials upon various friction testing machines. All of this matter has a value in showing the range of work which lubricants can be made to cover, and for the scientifically inclined it presents an interesting field for study.

Lubricants can be selected that will give a range of readings from the very lowest coefficients to the highest that it is possible to observe upon the testing machines in use. These machines are primarily intended as laboratory instruments, and in this field have a decided value in proving to the technical student that one set of lubricants will give different results from another under duplicate conditions of pressure and speed. While these friction testing machines are valuable in their special field, their readings are of little value when used to determine what lubricants should be applied for practical work.

A striking example of the limitations of testing machines is afforded by the following:—Lubricants offered to a foreign corporation were continually rejected, and upon investigation it was found that this was because the coefficients were high as compared with certain required book standards. As the oils were to be used for lubricating car journals, the following questions were asked in regard to the testing machine:—

Was the pressure over the entire bearing surface uneven?

Was the atmosphere surrounding the instrument bearing alternately cooled and heated; was it wet at one time and dry at another; was it dusty?

Was the speed variable?

Was the bearing treated with neglect?

These conditions the rejected lubricants were intended to cover.

As a matter of fact, the bearings of the machine were nicely ground; the pressure was evenly distributed by a clever arrangement of levers; the atmospheric condition was constant; the speed varied throughout a uniform range; and the oil was carefully measured out and the bearing flooded in a clear bath. All these conditions would be exactly the reverse in actual work.

There are instances where oils have been adopted for mill work from the results of tests upon friction machines. These oils, afterwards, have been replaced by other lubricants and considerable power has been saved as a result. Another instance is recorded where the best possible lubricant for the required purpose was rejected on account of its high coefficient as compared with that of a combination of light spindle and kerosene oil, an impossible practicable lubricant.

Many difficulties arise from selecting

oils for actual work by depending upon the comparative oil chemist. His reports are based upon characteristics of the given oils, and a selection made from such reports is made with an idea that greater or less reading of characteristics, such as temperature, gravity, or viscosity, proves the superiority of one lubricant over another for any given work. Gravity, viscosity, or temperature tests do not indicate the lubricating value of an oil; they show simply some of its physical properties.

The value of the oil chemist is in checking the various stages in the process of manufacturing the oil, and in this field his services are indispensable, as he protects both the manufacturer and purchaser from too wide a variation from the fixed standard. Should all oils be examined by the purchaser, through the chemist, it would be found that in consecutive shipments of certain classes of oils one consignment would vary more from the standard than another. Every characteristic of a certain oil has its standard reading, a variation of so many points each way being allowed by the manufacturer. The oil manufacturer who produces only lubricating oils will allow but little variation from his standard, while oils not primarily intended for lubricating purposes will vary so much from their standard readings that they might almost be classed differently.

Oils are classified as fixed and volatile. The fixed oils include the animal and vegetable oils and are not capable of distillation; volatile oils include the essential oils and petroleum.

Petroleum oils may be divided into two general classes,—the residual and distillate oils. The residual oils are products remaining after the light properties have been distilled off. There are almost unlimited variations in the character of residual oils, governed first, by the grade of the crude oil itself, and secondly, by the manner of distillation and subsequent treatment, which may vary from the most complete fractional distillation used in the manufacture of lubricating oils to that destructive distillation employed in the manufacture of burning oils, giving petroleum tar as the residual product.*

Distillate oils are of two classes; the paraffine oils made from distillation of the tar previously referred to, and afterwards deodorised and decolourised by chemical treatment; and the neutral oils which are made from an intermediate distillate produced in fractional distillation.

It is possible to duplicate an oil to within the variation allowed from the standard readings for that oil, duplication being in colour, weight, and all the known physical tests; yet upon actual work, where the requirements are exacting, the duplicate will break down completely, while the original will stand up to its work.

The most practical method of making a selection of lubricating oils is by an actual trial upon the machines to be lubricated. Sometimes these trials are very crude. Out of a large number of oils offered, one is selected that will stay on a bearing the longest; no observation is made except as to its lasting quality. While it is selected upon a comparative basis, a determination as to lasting quality does not necessarily signify that the oil is the best to use. Some selections are made after drying known quantities of the samples submitted, the purpose being to secure a non-gumming lubricant. Perhaps the method most widely used is to place the samples in the hands of the machine operators with instructions to watch the oils carefully. The difficulties in selecting lubricants in this way are that no ordinary operator is capable of judging the different stages of lubrication. Oil is reported upon as "all right," "no difference," or "it will not work." There might be ten oils that were all right, yet one would be much better than the others. In some mills where a practice is made of accepting all samples offered, the operators lose interest and send to the office the same report upon all.

For instance, one mill had for an agent a man who was constantly look-

* "About Lubrication, from the standpoint of a manufacturer of Petroleum Lubricants."—C. M. EVEREST; John Wiley & Sons, 1893.

ing for something better for lubricating purposes than he already had; but he took a wrong method of determining the comparative value of the material offered. On cylinder oils where the trial was based upon the amount of oil used for a specific work, the report given by the operators on nineteen samples was that they could see no difference in the feed,—for the very good reason, unknown to the agent, that they had always set the lubricators to feed so many drops per minute. The twentieth oil failed completely; they had to feed twice as much. They discovered the particularly bad oil, but they made no distinction between the other oils, which must have run from almost bad to very good; consequently no value was received by the agent from the trials.

Sometimes in changing oils and depending upon operators for a decision as to their comparative value, a wrong impression is made by the action of the new lubricant upon the deposits left by the old oil. This deposit in working out is very often charged up as belonging entirely to the latest lubricant, and a report is made to that effect.

Another very peculiar circumstance has been actually met with a number of times in mills where the method of lubrication has been an established factor for some years. A change of one set of oils having been made and an adverse report having been sent to the office by the operators, an investigation developed the fact that the hot bearings charged up to the new oil were not included in the test and had never had anything but the old oil upon them. They had been left undisturbed until the attention of the operator was called to the lubrication problem.

Some general system must be established by which the effect of lubricants can be determined in a practical manner. It must be along well-defined lines, and must be free from the personal factor item, from prejudice, from lack of interest, and from a too great amount of theoretical practice. Lubricants should be selected upon a basis of what they will do upon actual work towards reducing the frictional item to its lowest point. They should also be selected with an additional end in view,—that the frictional item should remain practically a constant, *i. e.*, the lubricants should not vary in quality, nor deteriorate during use, nor leave any deposit. The method of using them should conform to the class of work and to the results desired.

In treating the subject of lubrication from an engineering standpoint, using oils as a means of reducing the frictional horse-power of a textile mill, and making the different adaptations with a view of securing the lowest loss of power possible under running conditions of the mill, it is necessary that different classes of machinery be lubricated with oils of different characters.

It is impossible to more than generalise in regard to what special lubricants should be used for a textile mill, as the mechanical condition of each plant is a factor which will make it impracticable to treat all mills exactly alike. The machinery may be grouped, and the classifications of lubricants should generally be as follows:—

High-pressure cylinder oil.
Low-pressure cylinder oil.
Engine oil.
Dynamo or motor oil.
General lubricant for heavy machinery.
General lubricant for light machinery.
Shafting oil.
Loom oil.
Bath or closed spindle oil.
Oil for heavy open spindles.
Oil for light open spindles.
Top roll oil.

CYLINDER OILS

The following general conditions must be considered in making a selection of cylinder lubricants:—Location, size, and type of unit; general condition of cylinder and valves; pressure of steam; condition of steam; use of exhaust; method of oil feed.

The determination of the efficiency of cylinder lubricants is made by the manner in which the valves and piston operate during the run and by an inspection of lubricated surfaces after the run. The

lubricant should possess body and spreading qualities, and be able to remain upon the walls of the cylinder and upon the faces of the valves under the temperature and conditions of entering steam. It should not volatilise under working conditions, and it should not leave a resinous or tarry deposit upon the valves or in the cylinder clearance. The oil may be slightly compounded or not, as the condition of the plant may require. Compounding with the proper amount and kind of fixed oil adds to the lubricating value of a cylinder oil; but when the exhaust is returned to the boilers through a surface condenser and closed heater, as in all marine practice, a fixed oil in any amount or condition is detrimental to the efficiency of the boiler, and a cylinder oil composed of straight mineral stock should be used.

Oils must be adapted to the pressure and the condition of the steam used. High-pressure cylinders of multiple-cylinder units require an oil that will work with the temperature of the entering steam. Oil for the intermediate or low-pressure cylinders should be of an entirely different character, one more suited to the low pressure of steam and one that will work in harmony with the oil carried over in the exhaust from the high-pressure cylinder.

The amount of feed depends upon the condition of the engine and the steam, the character and the adaptability of the oil for the work, the style of the lubricator, and upon the engineer in charge.

A badly worn engine using wet steam will necessarily consume more oil for a given condition than an engine in good order using dry steam.

A light oil for high pressures will require a greater amount of oil to furnish the same amount of lubrication as a viscous oil. Overfeeding a viscous oil will usually produce an effect the opposite from that desired. Underfeeding a light oil will add to the abrasive friction of the engine. The feed of cylinder oil should be regular.

ENGINE LUBRICATION

Engines may be classed as high, medium, and slow-speed, and the oiling system as automatic and hand. An oiling system may be considered automatic where the oil is sent to the surfaces to be lubricated, caught after use, cleaned by filteration, and returned to the lubricated surfaces by force or by gravity. Sight-drop oil cups and open cups or bearings constitute the hand-oiling class.

High-speed engines are, as a rule, of the crank-case type, or are made practically enclosed by the use of oil guards or covers. Lubrication upon these engines approaches very nearly the oil bath. They should be fitted with a diaphragm or a double stuffing box so that the oil will not throw against the cylinder head, as the oil, in order to meet the lubrication condition of these engines, will not be sufficiently heavy to withstand the heat of the cylinder. Provisions are made on all the modern types of this class of engine to keep oil in circulation. In some types after the oil has run through the bearings, it is passed through a small filter and pumped back to the crank-case. The lubricant that is adapted to these engines should be a quick-acting, pure mineral oil, and should show clear after use. Water should separate freely from it, and it must not develop any decided tendency to thicken. An oil that is properly made for this work will last indefinitely, as far as wearing qualities are concerned.

Medium-speed engines require a little heavier lubricant, if oiling is done by hand, *i. e.*, through sight-drop oil cups. If the engine is fitted up to catch the oil after it has been used, a high-grade, indestructible oil should be adopted. This should be caught, filtered to remove dirt, etc., and reused. It should be an oil that will not break down through continued service, and should retain its colour, thicken but slightly, and contain no fixed oil., *i. e.*, animal and vegetable oil.

An oil for the heavier types of engine should be greasy, rather quick-acting, and should withstand pressure. If an automatic system is in use, the oil may be quicker-acting, so as to produce a bath effect instead of a drop film.

Wherever possible, and where the

greatest efficiency is desired, the drip for condensation and cylinder oil under the stuffing box should be separated from the drip from the guides. It is an easy matter in designing frames to allow for a short rib just behind the lower guide which will be the separating point for cylinder oil and engine oil. Should an engine not be arranged to catch all the oil, a lower grade can be used; but, as a rule, the lower grades of engine oils will not stand continued service, although they will do well enough if used only once. The practice of using an engine oil, catching it and using it again upon shafting and machinery in the mill, is not good economy.

Oils containing fixed materials leave a varnish-like film upon all bright work, and produce a pronounced deposit in the pipes and oil cups. Engines fitted with a gravity-feed system and using an oil of strong gumming tendencies, have to be given extra care, owing to the danger of the oil-feed stopping. Very frequently the piping has to be removed and scraped to secure a free flow of oil. Changing oil where this has been the case requires some care; the new oil, unless it contains the same amount of fixed product as the old, will act as a cleanser, loosening up the deposits in the system which will settle into the regulating gauge of the cup, and cause a stoppage of the feed. The piping should always be removed and cleansed thoroughly before changing from a gumming oil to one of different character.

Animal oils, or oils prepared by the use of acids, will attack brass and stain the bright work of engines.

DYNAMO OIL

Dynamo and motor oil may be lighter, quicker-acting oil than that used for engines. All modern electrical machines are fitted with ring-oiling bearings, and are very economical in their use of oil, which should be one that will not drop in efficiency through continued use. Thickening of the oil in a bearing of this design will result in the ring being retarded and the flow of oil over the shaft being lessened.

GENERAL LUBRICATION OF HEAVY MACHINERY

Openers, pickers, and cards are the heaviest and most important machines used in the ordinary manufacture of cotton or woolen goods. The best of care is used in setting up these machines, that they may be in perfect alignment, and all bearings true and to centre. To keep the bearings in this condition attention to lubrication is absolutely necessary. Fires in picker rooms are also frequently caused by lack of attention to lubrication. Oils should be fed by cups or bottles to all bearings that are taking all the work of the machine, and should be heavy and somewhat quick in action. They should show clear in colour after use.

Drawing frames should be treated with heavy lubricants. The top rolls require an especially heavy, greasy lubricant that will preserve a good wearing film for a considerable period. A compounded oil, an animal oil, or fat should not be used for top rolls, owing to the general tendency of these oils to oxidise and gum, thereby retarding the free movement of the roll, producing an uneven output.

GENERAL LUBRICATION OF LIGHT MACHINERY

Under this head should be classed all intermediate machinery, general lubrication of spinning frames, loose pulleys, and the light finishing machinery. This oil may be of such a character that it can be used upon the spindles of speeder and intermediate frames. It should be an oil of low fluid friction, non-gumming, and one that will stay in place.

If every ounce is required of the engine, and the mill is to be worked to its highest efficiency, in connection with the oil for spindles of intermediate frames and speeders, one of lighter body may be used for the steps. Spindles are usually oiled once a day, steps once a week, or at a longer interval, so that two oils can be used with but little trouble.

Spoolers, winders, beamers, and slashers may be treated under the head

of general lubrication of light machinery, and the same oils used upon everything in this class, excepting the artificially heated bearings of slasher rolls; on these the top roll oil should be used.

SHAFTING

Shafting should be fitted with the best lubricant for the condition under which it operates. A certain horse-power will be required to operate it under that condition. This horse-power should be as low as good lubrication can make it, and it should be kept a constant by the use of new, uniform oil; any admixture of filtered oils from engines or machines, or any use of grease will increase the power necessary to drive that shafting. Compounded oils, used upon shafting, offer great resistance to the free operation of that item, and make the power a variable factor, which gradually increases as the deposits in the boxes become more pronounced, until the additional cost for power to operate the shafting beyond its normal point exceeds the extra cost of lubrication of this item with the most expensive oil to be had. Bearings of whatever description require ordinary attention to oiling, otherwise the oil will overflow. In textile mills tin guards or drip cans are usually provided, as a precautionary measure, to prevent oil from getting upon the goods in transit or process of manufacture.

Shafting hangers may be grouped as "open" and "ring oiling," and may be treated in three ways. Open boxes, if they are new, can be lubricated with a quick-acting oil. In general character it should be adhesive, greasy, and as fluid as the condition will allow. Open shafting is sometimes fitted with bottles having spindles, which, during the operation of the shafting, cause the oil to flow slowly. If these bottles are carefully adjusted and an evenly constructed oil is used, an even condition is produced; but it is necessary to keep a uniform grade of oil supplied to the bottles after once adjusting them, and the oil should not contain a fixed material or leave any deposit; otherwise the bottles, instead of being of service, will be quite the reverse.

Open shafting hangers that are badly worn and receive but little attention require a heavier oil, one that will act as a cushion, stay where it is put, and prevent the hammering frequent in a worn box, and consequent loss of power by abrasion.

Ring-oiling hangers should be oiled with a light-bodied oil,—one that will stand wear. The general characteristics for open work should also govern; that is, the oil should be greasy and should not leave a deposit, but the main point is that its initial efficiency must last. Where an open hanger is oiled at least every other day, a ring-oiling hanger runs from one to six months. It is, therefore, necessary to have an oil that will retain its original character so that the power to drive the shafting may be a constant throughout the period between the oilings.

LOOMS

Outside of the spinning frame, no other class of machinery claims so much attention from the lubrication standpoint as looms. It is not power-saving, but "stainless," quality that is required of a loom oil. It is a generally acknowledged fact that no oil is stainless in the exact meaning of the word. In attempting to secure a stainless oil, the power question is entirely lost sight of. The proper treatment of the subject should result in not only saving power, and in doing away with those effects which a stainless oil is intended to overcome, but should also save the wear of the loom, as well as the amount of oil used.

It must be borne in mind that all oils are dark-coloured to start with. A "stainless oil," or an oil that is white or nearly so, is manufactured by a bleaching or filtering process that takes out certain hydrocarbon qualities that are essential. This bleaching process leaves the oil rather characterless; it has nothing much to recommend it except its good appearance before using. It will turn black after use, carrying with it iron in solution, and iron in particles, evidences of lost power through abrasion; and it will damage any goods with which it comes in contact, the oil itself

not causing so much trouble as the iron carried with it.

Compounding the bleached oil with an animal or fixed oil, while holding up the body, brings another element into the problem, that of gumming, and deposit-leaving, which acts against the power by presenting a poor lubricating surface to the lubricant. Straight animal oils should not be used, owing to their tendency to oxidise.

In treating this subject, the natural condition of the present loom must be considered. An ordinary cotton loom cannot be compared at all on a mechanical basis with any other machine in a mill. It is always badly out of line, the boxes are always loose, the shafting is rough, the cranks are roughly turned out of a forged bar, and the whole machine during operation pounds and shakes. However, it meets the conditions for which it is built, can be built cheaply, and can be renewed at little cost when worn out or when improvements of parts make its operation unprofitable. Upon this machine, instead of a light-coloured, light-bodied oil that shows black after use (a good indication that its lubricating power is very low), a greasy, heavy oil should be used, one having the essential characteristic of staying where it is put; not necessarily a stocky oil, but one of body. The colour should not be considered. An oil of this character will stay in place, keep lubricated surfaces apart, prevent wear and the effect of wear. It will not drop or throw on to the goods, can be used in small quantities, and should reduce the power required to operate the loom by preventing actual metallic contact of the surfaces.

SPINDLES

Spindle lubrication is probably the most important item in the mill, and much has been written on this one subject from a practical standpoint. It was stated some years ago with the advent of the Rabbeth or bath type of spindle, that a so-called light gravity oil was the best to use for economising power. After the subject had been widely discussed, there seems to have been no concerted action on the part of users of these spindles to arrive at a standard. Some go further than the light-oil theory, and use an oil too light, working entirely from a gravity standpoint, thinking that the lighter the oil, the easier the spindle will operate. Black, worn spindles, and large renewal bills with a constant expenditure for power consumed by abrasion, are the usual results of such practice.

An oil, to be a good spindle lubricant, must have other characteristics besides light gravity. It must be homogeneous in character; that is, so constructed that it will not change in lubricating value from oiling to oiling; the power to drive spindles must not increase as the oil wears until just before the renewal of the oil it is taking a great deal more power than absolutely necessary. The oil must be strictly neutral, and absolute freedom is necessary from material that will gum and attack metal. Moisture in a spindle oil produces a brown rust; acid will produce rust and attack metal; gumming will greatly add to the power to drive spindles. Spindle oils that contain any of the fixed oils will leave a varnish-like deposit over all of the running part of the spindle except the foot, and over the bolster and in the base. This film causes loss of power by means of offering extra resistance to the revolving oil. A smooth, clean spindle and bolster with a dry, clear, quick oil are necessary in order to secure the best efficiency.

The most power in spindle work is lost through the oil friction of the lubricant used. The oil should be of sufficient weight to keep the surfaces a part under the light pressure of band pull and load, and should work upon itself with the greatest ease. The construction of such an oil enters largely into the problem. One that is made by a destructive method of distillation, where the molecular parts are altered by burning, and where this charring and burning effect is partially removed by the use of acids, will not work well upon itself. Every care should be exercised in the various stages of manufacture of a spindle oil, as it must run uniform in

grade and quality. One bad barrel will affect the power of an entire room, and may cause endless annoyance, besides loss of production and power.

Bath spindle oil, from an oil manufacturer's standpoint, is a very small item. It is a small item to the mill when compared to the total lubrication bill. This oil should not be overlooked, however, as there is no single class of machinery that is so quickly influenced and that responds so readily to lubrication or the lack of it as the modern spindle.

Spindles of the Sawyer or open type require a more stocky lubricant, as there is no mechanical method of retaining the lubricant upon and around spindle and bolster other than the nature of the oil itself. In extremely fine cases it is possible to use two oils, one for the bolster and another for the steps. The latter may have the same characteristics as the bath spindle oil, but it will have to be applied more often.

Mule spindles, if new, may be treated the same as the lighter Sawyer or open spindles by using two oils, one for the bolster and one for the steps; or one oil weighty enough for the bolsters may be used all around. If the spindles are worn badly, as is the case in most old machines, the extra bolster oil is almost a necessity. It should be an oil about twice as heavy as that used for Sawyer spindles. This will effect a cushion, prevent abrasion and consequent loss of power. The initial power required to operate with the heavy oil will be greater, but there will be no loss caused by the surfaces coming together, as they eventually would if a light oil were used. If a mule is noisy, and produces a sharp, dry rattle, this treatment will invariably show a decided and immediate improvement.

Twister spindles and heavier spindles of bath types should be treated the same as the regular bath spindles, if power is being considered. The only change, owing to the extra weight of the spindles, would be to oil up more frequently; where this is not done an oil heavier in nature must be used.

TOP ROLLS

Top rolls, as in drawing frames, whether solid or shell, should be oiled with a mineral, non-compounded oil, which should be the heaviest oil used in the mill, outside of cylinder work. It should be a stocky, greasy, mineral oil that will not flow readily so as to run out on the leather covering, or onto the yard. While the speed is slow and the weight light, and the power, as compared to the frame, small (probably eight per cent.), the drawing roll condition from a production standpoint is an important one, and a well lubricated condition is necessary to the smooth running of the work in the machine and during the after processes.

The cost of oil should never be considered in selecting lubricants, since a reduction of seven per cent. in the total horse-power of a mill through reduction of frictional losses will usually pay for the entire oil consumed. Three per cent. saved from the total horse-power of a mill will more than offset any increase in yearly cost, from the very cheapest oils to the most expensive adapted lubricants. In many modern mills there is no investment which can be made for new machinery, or any improvement in system of operation, or reduction in cost of production which will give the immediate financial results that attention to lubrication from an engineering standpoint will produce.

Current Topics

THE great strike in the American anthracite coal fields, which was temporarily settled a few weeks ago after more than five months' duration, demonstrated once more, and perhaps better than any previous strike in any branch of industry, that organised labour and organised violence and contempt of law and order are often pretty close companions. From beginning to end the strike was characterised by disgraceful acts of destruction of property and attacks upon the lives of non-union mine workers, all of them supported, morally at least, by government inaction at a time when prompt and energetic measures should have been taken and would have borne good fruit. All these exhibitions of vicious lawlessness and the dangers of cheap politics, however, might well be forgotten if any good were to come from this industrial calamity. Some may come from the work of the Anthracite Coal Strike Commission which was appointed by the President of the United States to investigate and report upon the conditions under which coal is mined and handled in the Pennsylvania anthracite regions; but there is little probability that its labours will have any lasting or definite value. Arbitration, the goal toward which the Commission is working, is, after all, only another name for compromise, and compromise is a sorry kind of thing where a question of absolute right or wrong is involved.

THE real hope of profit from this strike is centered practically altogether in a proper and wide-spread recognition of the fact that a labour organisation, in order to be permitted to exist and in order to command respect and confidence, must become pecuniarily responsible for the actions of its members and for whatever contracts it makes. Responsible capital dealing with an irresponsible mob presents a condition which long ago should have been wiped out, and there never was a better time than now to suppress the growth of that species of anarchy of which some branches of organised labour are representative at times of serious disagreement with employers.

AMERICA has something to learn in this respect from Great Britain, even though trade unionism has there-

THE LARGEST STEAMSHIP AFLOAT. THE NEW NORTH GERMAN LLOYD LINER "KAISER WILHELM II.", LAUNCHED AT THE VULCAN WORKS, AT STETTIN, GERMANY, ON AUGUST 12, 1902. LENGTH, 706 FEET; BREADTH, 72 FEET; DISPLACEMENT, 26,000 TONS; I. H. P., 40,000

FROM A DRAWING BY WILLY STOWER

always been supposed to flourish in its most virulent form. Compulsory arbitration, which was once hailed by British labour unions as the only way to salvation, is not quite so popular with them now as it was a few years ago, and there is reason to believe that this is in no little measure because of the trains of thought aroused by the famous Taff Vale Railway decision a few years ago. This judicial decision was, briefly, to the effect that trades unions were responsible for their conduct and for the conduct of their members, and that such responsibility could be legally enforced by levying upon the funds of the unions for indemnity for illegal acts. In other words, if the unions are to enjoy power and authority they must suffer responsibility; if they can accumulate great funds and use them in fighting employers of labour, those funds must be accessible and accountable through process of law, as vouchers of the unions' responsibility. Thus the funds of the unions would be not only a means of sustaining a strike, but also a hostage for the lawful conduct of the strike, and a tangible asset, which could be levied upon just as much as the capital or other property of the employers of labour, whether for indemnity for illegal conduct or for enforcement of the fulfillment of contract. That obviously changes the face of affairs in a marked degree. Under that decision the trades union can no longer enjoy power without responsibility. If it breaks a contract, its funds may be attached for penalty. If its members break the law in carrying out a union's orders, it may be fined and may be mulcted in full indemnity for damage done. That may seem a serious and unwelcome thing to some unionists, but the most thoughtful and fair-minded of them will be constrained to recognise, with the rest of the community, the soundness and equity of the principle. If the capitalist's funds or property can be levied upon to hold him to his contract or to punish him for wrongdoing, so should the funds of the union be amenable in similar cases. If the realisation of this principle should become general, and should induce greater sobriety of thought and conservatism of action, there would be great gain to both capital and labour.

ONE of the notable engineering events of the year 1902 was the launch, last August, of the North German Lloyd Atlantic liner *Kaiser Wilhelm II.*, which is not only the largest ship yet built, but is to be the fastest as well, and certainly will be the most powerful, with propelling machinery of 40,000 indicated horsepower. Twenty-six thousand tons displacement, 706½-foot length, and 72-foot beam, added to the above horsepower, will, roughly, give one some sense of the hugeness of this latest product of the famous German Vulcan Works, at Stettin. In some measure, too, the illustration opposite will help in this, the original drawing having been carefully prepared under the supervision of the designers and builders of the ship. Twenty-four knots are to be the regular speed to be attained. The vessel will accommodate 775 first-class passengers, 343 second-class passengers, and 770 third-class passengers, while the ship's complement itself will consist of 600 persons, comprising 48 engineers and assistants; 229 stokers and trimmers; 170 stewards, stewardesses, and 'tween deck waiters; 61 cooks and pantry-men; and 45 sailors. The propelling machinery for the twin screws consists of four four-cylinder, three-crank, quadruple expansion engines. The two engines for each shaft are placed behind each other in order to admit of the construction of a transverse watertight bulkhead, in addition to the longitudinal partition, so that each of the four engines is within a separate compartment. These engines each drive a four-bladed bronze screw propeller about 23 feet in diameter. The crankshafts and the thrust-shaft, 25 inches in diameter, are made of nickel steel; the screw-shaft, 25½ inches in diameter, is of crucible steel; and the whole connecting shafting is of Siemens-Martin steel. Steam will be supplied by twelve double and seven single boilers working at a pressure of 213 pounds

and having 107,643 square feet of heating surface. The 124 furnaces have 3121 square feet of grate area. The boilers are arranged in four groups, each having a funnel somewhat over 16 feet in diameter and 131 feet high, that is, above the keel. The boiler rooms are ventilated naturally by means of large cowls, but this natural ventilation is materially assisted by the working of eight powerful ventilating fans. The number of engines on board, including the main engines, is 79, comprising 124 steam cylinders. The launching weight of the vessel amounted to 11,200 tons, while that of the *Deutschland* was 9300 tons, and of the *Kronprinz Wilhelm* 8950 tons. The *Kaiser Wilhelm II.*, with 706½ feet in point of length, is 2½ feet longer than the White Star Line *Oceanic*, and 6½ feet longer than the twin leviathans *Celtic* and *Cedric*, of the same line.

CONTRARY to the view held by many because of the application of the term galvanising to the mechanical coating of metals with zinc, this term did not owe its existence to any actual electric deposition of that metal or other metals; but apparently the term was due to the successful experiments of Humphrey Davy, who, in the early part of the last century, availed himself of the galvanic action between zinc and iron to guard the latter against corrosion, by applying strips of zinc to the iron when immersed in sea water, for instance, in the case of the hulls of ships, the iron in this way being protected at the expense of the more costly metal zinc, which fact doubtless operated somewhat against the general and continued utilisation of this galvanic method of protection. The mechanical deposition of a coating of molten zinc upon iron, popularly termed galvanising, as a protection against corrosion of the iron, has been in extensive use for years, and perhaps for nothing more extensively than iron telegraph wires and iron screw bolts for insulators. The zinc protects the iron by combining with the oxygen of the air, forming an oxide of zinc that is not attacked further, unless in the presence of gas or fumes, such as sulphuric acid, which combines with the oxide, forming sulphate of zinc. This, being soluble in water, is quickly washed off by rains, leaving the iron unprotected, when it soon corrodes and becomes useless. It is, by the way, one of the greatest mechanical advantages of hard-drawn copper wire over galvanised iron wire for telegraph purposes that it is practically indestructible under like conditions.

IN recent years the electric deposition of zinc upon other metals has received considerable attention, and numerous establishments have been equipped to carry on this industry. This latter process has numerous advantages over the mechanical deposition of zinc on metals for many purposes. Thus the electric, or true galvanic, method of deposition may be employed in many cases when the heating of the metal to the point at which the zinc adheres to it, would be fatal to its use. Again, it can be employed where a very thin coating of the zinc is essential, as in screws, screw bolts, door hinges, etc., where the hot or mechanical process is not always applicable, or, if so, not without some after treatment to remove the excess of zinc. For telegraph wire purposes the electric process would hardly be available, being too slow and too expensive. It may, however, be noted that the electrolytic deposition of copper on a steel wire was once carried on to quite an extent, and at least one circuit between New York and Chicago, measuring about 1.5 ohm per mile, is composed of this compound wire.

THE base of the electrolyte used in the process of zinc electro-plating is usually a zinc sulphate, with a small amount of sulphuric acid, and one or more of a number of other compounds, such as aluminium sulphate, which have been found to improve the nature of the deposited zinc, the zinc sulphate being

placed in the solution in the shape of a white dust. On account of the reasons indicated, the sulphate of zinc is now in considerable demand, at a fair price. This sulphate, or "white salts," as it is termed, is, or rather was, the *bete-noir* of telegraph battery men before the dynamo machine displaced the gravity, or Calland cells, in all of the large telegraph offices. In the operation of this cell the copper of the copper sulphate, or "blue vitriol," solution is deposited as metallic copper on the copper plate of the cell, while the metallic zinc plate of the cell is dissolved, forming a sulphate of zinc solution. By capillary attraction this solution rises over the edges and runs down the sides of the glass cell. After a time the water of the solution evaporates, leaving a covering of the sulphate of zinc in the shape of a soft white salt extending from the cells to the battery stands, and inasmuch as the zinc sulphate is, in its humid state, a good conductor of electricity, it frequently short-circuited the battery. After this battery is exhausted, the solution consists almost entirely of zinc sulphate, and as there was at the time mentioned no market for it, thousands of gallons of the solution were annually emptied into the sewers, where possibly it served some purpose as a germicide! There were, of course, many experimenters who endeavoured, without success, to discover some economical method of recovering the zinc in metallic form from the waste zinc sulphate solution, there being quite an incentive for so doing, as will be understood when it is considered that in a telegraph office employing 10,000 or 12,000 such cells the value of the dissolved zinc was from $4000 to $5000 per annum. There are yet several millions of gravity cells in service, but usually they are now so widely scattered in small lots it would be impracticable to collect the zinc sulphate for sale as a by-product.

WHAT type of steam engine will supply power most cheaply? The scientific man, and the theoretical, said the London *Engineer*, in a recent discussion of this question, will naturally jump to the conclusion that the engine which uses least steam per horse-power per hour will best satisfy the conditions. But the steam user has only too good reason to know that the question is much too complicated to be answered in this way. Taking coal to cost one-tenth of a penny per pound, or a little over a sovereign per ton,—a reasonable price for steam coal,—it will be seen that if 1000 I. H. P. is obtained for an hour with 2000 pounds of coal, the cost is 17s. 6d. A reduction in the consumption amounting to the not inconsiderable figure of 14 per cent. would represent a saving of but half-a-crown. It is in no way certain that in the long run, of two engines, one using 14 per cent. less steam than the other, the first would be the better engine to have. It might be or it might not be. It is to a problem of this kind that the engineer preparing designs for an electricity installation must address himself; and to find the correct answer will severely tax all his skill and ability, for so much is promised, and so much is actually performed by the makers of high-class steam engines, that it is by no means easy to decide between conflicting claims.

THERE are, however, certain broad principles which will serve to guide the engineer. It will usually be found that high economy means, if not complication, at all events an increase in the number of parts, and a high steam pressure. To these things there is no objection so long as it is fully understood that they demand superior material and very excellent workmanship. The highly economical engine must, therefore, be comparatively an expensive engine. If it is not expensive at first, it is sure to be costly in the long run. Thus, for example, with high-pressure steam and a high piston speed, it is essential that the cylinder liner metal, particularly if the engine is horizontal, shall be as hard as is compatible with boring. This means that the liners will

cost a good deal of money. If soft metal is used, the result will be serious. Furthermore, it must never be forgotten that the primary condition of working is that the engine shall never cease running until the engineer in charge stops it. That is to say, it must not get hot bearings or break down in any way. Now, engines with complicated valve gear are not invariably trustworthy in this respect. They are not trustworthy at all unless they are extremely well designed, made, and maintained. These and various other considerations all point to the one end. The very economical engine must be a very fine piece of mechanism, and it must be taken in charge by competent men. It is the old story of the astronomical regulator and the kitchen clock over again.

If, now, the engineer is told that he can have the economical engine for the same price, or nearly the same price, as the engine of a simpler type, he will do well to regard this statement with suspicion. It is quite possible to build a cheap engine which will give a very high result for a short time. In the end it will prove a weariness to the flesh of everyone who has to do with it. On the other hand, the first cost, and the other costs involved in the purchase and use of a very economical and beautifull engine may be so great that the saving effected in fuel will not compensate for the augmented outlay. Anyone ought to see at a glance that at this point we are brought face to face with the cost of coal, and thus an engine which might be highly desirable in one place where fuel may be very dear might not be at all the best. in the centre of the coalfields.

The destructive effects of electrolysis upon the gas and water pipes of cities, due to stray currents from electric traction roads in which the rails are used as the return circuit, is at the present time receiving renewed and increasing attention. The positive remedy, namely, the use of the double trolley, or its equivalent, is vigorously opposed by the users of the single trolley and track return, owing to the complications and cost of the double trolley method. The makeshift remedy and the one most generally applied hitherto has been to bond the rails as thoroughly as possible, and when investigation shows that, notwithstanding this bonding, currents are entering and leaving the gas and water pipes, to connect the latter by heavy copper wire to the tracks as near the power house as practicable, thereby to provide an unbroken metallic circuit from the pipes to tracks, it being well known that electrolysis occurs only at the points where the current leaves the pipe and uses the damp earth as part of the circuit. The compounds of ammonium, sodium, etc., in the earth at such points are decomposed by the current and the metal of the pipes is thereby attacked. Where pipes have been thus connected with the rails, measurements have shown that in some cases the pipes were carrying over 300 ampères of current. When it is considered that one ampère of current flowing steadily from an iron pipe in a suitable electrolyte will corrode one pound of that metal in one year, the possibilities of damage to underground metal structures from the cause in question may easily be recognised.

It has been suggested recently that damage to pipes from this cause may be averted by insulating the joints of the pipes at more or less frequent intervals so that they shall offer a poor path for the return of stray currents. It would seem, however, that this plan would be available at best only in the case of new pipe lines, or in single instances, for obviously it would not be practicable to disturb the entire pipe system of a city to insulate the joints. Besides, it has yet to be demonstrated that a durable insulating joint for gas and water pipes is procurable. Vulcanised fibre has been proposed, and, in fact, tried with some success for such joints, but this material does not yet meet the general

approval of gas engineers. Perhaps relief from electrolytic damage of the nature in question may ultimately come by the compulsory employment of the double trolley system, or by the adoption of the alternating current, when a practical alternating current system and single-phase motor shall have been evolved, in place of the direct current systems and motors now almost universally employed for electric traction purposes. It is within the possibilities that this consummation is not so remote as may be generally thought, a single-trolley railroad in which single-phase motors will be employed having already been contracted for to connect the cities of Washington, Baltimore and Annapolis.

REFERENCE was recently made in these columns to the severe losses that telegraph, telephone, and electric light and power companies have to undergo on the occasion of severe sleet storms by reason of damage and sometimes disaster to their overhead wires. It has, heretofore, been considered advisable to shorten the span between poles as much as practicable in order to lessen the load upon individual poles, so that it has not been uncommon to have thirty, forty or fifty poles to the mile. While this practice is warranted in some respects, it also has its disadvantages, among which are greater first cost, as well as the subsequent greater cost of maintenance. For example, taking a 30-wire telegraph line, the difference in amount of material between a 35 and a 50-pole-per-mile line is, insulators and tie-wires, 525 per mile; cross-arms, 75 per mile. In a 300-mile pole line this would amount to 175,000 insulators, the same number of tie-wires, and 23,500 cross-arms in favour of the 35-pole-per-mile line. As each tie-wire is about 18 inches long, this is equal to about 45 miles of wire. The foregoing takes no account of the additional cost of labour in the construction work. Unfortunately, also, when a disastrous storm comes, it is not uncommon for one pole after another to fall, like bricks in a row, for hundreds of yards, showing that even the highest number of poles now used is not a certain preventive of such collapses. There is also an electrical objection to the multiplication of poles, namely, the lowering of the total insulation resistance of the line thereby, especially in wet weather. It is, therefore, not astonishing to learn that some of the long-distance power transmission companies are seriously considering a radical departure from the conventional practice, proposing to dispense with poles altogether, and in their place to erect large towers, 60 feet high and 1000 feet apart, on which they would string their heavy conductors 9 feet apart. Assuming that this plan will be found feasible, it is reasonable to assume that the cost of, say, five such towers per mile will not much exceed that of the forty or fifty poles per mile line. With proper precautions the life of such towers should be very long, and the cost of maintenance comparatively low. This proposed departure would not be altogether an experiment, for it was frequently necessary in the early days of telegraphy, and before the advent of submarine cables, to employ long spans of wire to cross rivers and bays. For example, there were several spans of wire over 2000 feet long across the Elba and other rivers in Continental Europe, and prior to 1847 the Hudson River, in the United States, was spanned by a number of wires from Fort Lee to Washington Heights, which was then ten miles out of New York city, but is now several miles within the city limits. At that point the river is 2700 feet wide, and it was the custom to lower the wires into the water to permit ships to pass, for which purpose men were stationed at the crossing. The Mississippi River also was spanned in this way in several places, and at one point where the river was 3720 feet wide, the wires, No. 16 hard-drawn iron, were supported on masts 307 feet in height.

BUT there are much more recent instances of the employment of long spans

A 35-TON HORIZONTAL DUPLEX STEAM HAMMER IN THE SHOPS OF THE LANCASHIRE & YORKSHIRE RAILWAY, HORWICH, ENGLAND

of wire for electrical purposes across bodies of water where, for example, the nature of the bottom or the prevalence of rapid currents and ice, make it impracticable to maintain cables, or where, in other cases, the electric pressure on the circuit is greater than can safely be carried in a cable in the present state of the art. Thus, a telephone cable 3200 feet in length, with ten pairs of conductors, suspended from poles 270 feet high, spans the Susquehanna River, in Pennsylvania; and across Carquinez Straits, in California, the four heavy conductors of a power transmission line carrying current at a pressure of 60,000 volts are strung from iron towers 225 feet in height and 4427 feet apart.

ANOTHER plan to ensure reliable telegraphic communication, regardless of weather conditions, is now being mooted in Great Britain, where serious interruptions to the telegraph service, occasioned by severe storms, have been repeatedly suffered. It has been noticed that at no time since the successful laying of the Atlantic cables has telegraphic communication between Europe and America been interrupted, and, in fact, that at the time of the great American blizzard of 1888, which extended over a large portion of New York and New England, the only telegraphic communication possible for many hours between New York and Boston was carried on by way of the Atlantic cables. The suggestion, therefore, is to connect the important sea-coast cities of Great Britain by submarine cables, which can be laid more rapidly, and, if anything, more economically, than underground cables, of which latter, it may be noted, more than one have been laid, a 76-conductor cable, for example, which has been in operation for several years between Birmingham and Liverpool. Should this plan of connecting the seaports of Great Britain by submarine cables be adopted, however, it will not be altogether original, inasmuch as this method of connecting a number of the chief ports of the islands of the Philippines has already been put into practical operation by the United States Government, not, however, so much to secure immunity from interruptions of service due to storms, as because of the present nature of a great portion of the country which makes the construction and maintenance of pole lines a matter of almost insurmountable difficulty.

A HORIZONTAL steam hammer, and of a duplex type, too, is quite unusual enough to lend a special interest to the illustration on the opposite page, showing such a contrivance in the shops, at Horwich, of the Lancashire & Yorkshire Railway. The engraving shows also the overhead travelling crane and other mechanism for carrying the ingots under treatment from furnace to hammer. The movement of the ingot to and fro is hydraulically operated by a man who stands at the lever shown in front. He has complete control of the machine, with a clear view of the work. It will be observed that foundations such as are requisite in a vertical steam hammer are needless in the case of the one under notice. Each hammer head acts as an anvil for the other, the impact of the blow being absorbed mutually. In comparing the work of a single 35-ton hammer it is evident that each blow of this duplex 35-ton design has to be through only one-half the space in order to produce the same effect, and a greater number of blows can, therefore, be given in the same time. The blows, also, being in opposite directions, counteract one another with a resulting absence of vibration.

URALITE is the latest fire resisting material to claim the attention of engineers, its name being due to the fact that its inventor, an officer of the Russian army, was stationed near the Ural Mountains, and that a part of its substance, the asbestos, comes from that quarter of the world. The asbestos is ground to pulp and mixed with about 30 per cent. of chalk, to fill up the interstices between

the short fibres, and, after passing through various chemical processes, appears in the form of tough, pliable strips. Gelatinous silica is used as a cementing substance, about 20 per cent. being used, thus leaving the proportion of asbestos about one-half of the total. The boards made from this substance are claimed to be tough and to stand a large amount of wear and tear, but their chief interest arises from the fact that they appear to be utterly impervious to fire. According to what particulars are available, they may be planed or sawed like ordinary wood, and glued or nailed with equal facility. Numerous experiments have been made with the material, all intended to demonstrate its superior qualities as a fire resistant, and all appear to have been successful. Doors made of it have withstood extreme temperatures without injury. A deed box was subjected to a very hot fire for an hour and a half; when opened, it was found that the papers were not even charred. As a material for constructing file boxes and in various other ways where papers are to be preserved, it would thus seem to have a large field of usefulness. Its application on shipboard may be another important field.

THE use of a sand box under the foot of a column which is to be lowered slowly has been proved to be very old by recent discoveries in Egypt, mentioned in the *Engineering Record*. Three similar tombs were found near the pyramid of Onnos, all dating from about 500 B. C., and one ready for the interment of a mummy. It was a chamber about 17 feet long, 9 feet wide and 10 feet high to the crown of the arched roof of large cut stones, the first stone arch of the kind on record. The sarcophagus was in place, and over it was the heavy limestone cover slab which was to be lowered when the mummy was in position. This stone was 13 feet long, 3 feet thick, and just a trifle narrower than the tomb chamber. It was upheld by six rough pillars of inferior workmanship to the other masonry and evidently temporary, and had two massive tenons on each side, fitting in vertical slots or niches in the walls. These niches were carried down about 6½ feet below the floor of the chamber, and in them would be placed sand to support wooden posts on which the weight of the slab, about seventeen tons, would come when the temporary masonry pillars were removed. Between the two niches on each side of the chamber a pit was excavated, large enough to hold a man, and the niches had openings at different elevations connecting with this pit. When it was time to lower the stone, it would only be necessary to have a man enter each pit and open these passages one after the other in order to allow the sand to escape and the timber posts to settle slowly. Such posts were found in the niches of the two tombs containing mummies. When the slab was in place the men could crawl over it and thus leave the chamber.

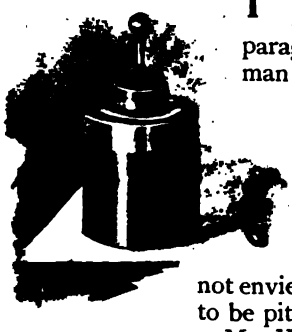
IN the practice of telegraphy it is an easy matter to transmit messages automatically from one wire into another by means of what are termed repeaters, the current strength employed in that art being of sufficient strength to operate apparatus that virtually takes the place of the operator's ear and hand, at a repeating station. By the use of the repeater it is feasible to operate circuits extending over several thousand miles without human intervention. In telephony, however, the current available is so exceedingly weak that attempts to operate automatic telephone repeaters, or relays, analogous to those used in telegraphy over unlimited distances have been futile. It has been found feasible to obtain automatic repetition of the voice from one wire to another in a number of ways, but the volume of sound at the receiving station has been no greater than that obtained over the same distance without a repeater. The value of a practical device of this nature in telephony is obvious, and as an incentive to inventors the president of one of the largest American telephone com-

panies a few years ago offered a prize of $1,000,000 for a practical telephone relay, but without a successful claimant. That inventors are still at work upon this problem is, however, evident from the occasional appearance of letters patent for telephone relays. One of the latest of these, the Lyons telephone relay, has been assigned to the largest long-distance telephone company in the United States, and may, therefore, be assumed to possess some promise of ultimate practicability. Strictly speaking it is a current re-enforcing arrangement.

GEORGE WESTINGHOUSE

A BIOGRAPHICAL SKETCH

By Walter M. McFarland



IN a popular magazine article some months ago occurred this paragraph: —"The rich man who stands alone, who has not established something, who is not identified with some great institution, commercial or public, is not envied. He is more likely to be pitied."

Mr. Westinghouse is a remarkable example of a rich man who is not only identified with great institutions, but who has made them great himself, and has become wealthy in doing so. The process has not been an easy one, and his is a striking illustration of the "strenuous life."

In these days, when there are so many instances of millionaires who have started as poor boys, there is a tendency to think this true of everyone who is not known to be the son of a rich man; but Mr. Westinghouse's career lacks that touch of romance. His father was a successful manufacturer of agricultural machinery, and the old factory is still in operation at Schenectady, New York. His family moved to that town in 1856 from Central Bridge, Schoharie County, New York, where he was born in October, 1846, so that he is now about fifty-six, still a young man as we count age in these days, and certainly a splendid specimen of physical and mental vigour, for he works harder than any of his numerous assistants, and finds his relaxation rather in a change of work than in complete cessation. He is a man of large frame, which probably explains how, although only a boy, he was allowed to take part in the American Civil War, seeing service in the cavalry and infantry of the Army, and, towards the end of the war, as an engineer officer in the Navy, where his mechanical aptitude found a congenial occupation; for it must not be forgotten that the basis of his success is in his great mechanical genius, both in manipulative skill and in that bent of mind which, seemingly by intuition, sees at once the practicable and the reasonable in mechanical contrivances, and does not have to grope after a proper solution of mechanical problems.

Mr. Westinghouse's career is an illustration of evolution throughout. His first invention was a railroad frog, which was quite successful, and it was while exploiting this and naturally studying railroad problems that his attention was drawn to car brakes. They were crude enough before his great invention of the air brake, which has made his name known throughout the world wherever the railroad has gone. His first thought was a steam brake, but his knowledge

as an engineer showed that condensation would make this a failure.

About this time the Mont Cenis tunnel was building, and the technical papers told of the successful transmission of power by compressed air. Everybody had the same chance to see what this meant; but his was the mind that grasped the hint, and the result was the air brake. Of course, it was crude as compared with the perfected brake of today, but it revolutionised railroading by enormously increasing the safety of operation and by making higher speeds possible. His later invention of the triple valve and of setting the brakes by releasing the pressure in the train-pipe was almost as important as that of the air brake itself, securing, as it does, simultaneous action of all the brakes in a train, with the added benefit that if the train separates, the brakes are set at once.

The history of the introduction and progress of the air brake is fascinating enough to warrant a long article by itself; but Mr. Westinghouse has done so much, and in so many fields, that we cannot dwell on this side of his work. If he had never done anything else, the invention of the air brake would entitle him to a high rank among the benefactors of humanity, for it has made modern high speed railroading possible and safe.

There are three marked characteristics in Mr. Westinghouse's talents, as an inventor or mechanic, as an executive and organiser, and as a financier. The first was shown in the invention and improvement of the air brake. The second had its first illustration in the works which he organized for its manufacture. These have, of course, grown with the years, like everything else he operates, and they now present one of the most efficient cases of highly specialised industry in the world. They have proved a veritable gold mine for the stockholders, and yet such is the economy of manufacture that the workmen get high wages, and the product is cheaper than any competitor, unless organised on such a perfect scale, could turn out. This was demonstrated to be a fact by a large railroad which, for a time, made its own brakes on a very low royalty. They found it cheaper to buy them from the Westinghouse works at Wilmerding.

His mastery of pneumatic devices led him to adapt compressed air to railway switches and signals, out of which came the Union Switch & Signal Company, which has installed the switching and signaling plant in such complicated stations as the great South Terminal at Boston and the Union Station at Pittsburgh. Electricity came to take a place in this work for the automatic signals, and it was through the acquaintance thus gained that he was led into the field of electric development, where the history of his work is even more romantic than that of the development of the brake.

Those who have known him best and longest have constantly remarked upon his wonderful foresight and prevision, of which a few instances will appear as we proceed. Nearly twenty years ago he seemed to grasp the possibilities of electrical development, when the art was truly in its infancy. It was evident that the field for direct current was limited, and that for transmission over long distances alternating current must be used; but something was necessary to change the small current of high potential to the stronger current of practicable voltage. The Gaulard and Gibbs patents were brought to his notice, and he purchased them for the United States. Just here we may note another trait in his character, the readiness, although an inventor himself, to purchase and use the inventions of others. With the control of these patents, he organised the Westinghouse Electric Company, which has grown until it is now one of the greatest manufacturing companies in the world. The history of the introduction of alternating-current machinery is truly that of the "strenuous life" for Mr. Westinghouse. It met with desperate opposition from the makers of direct-current apparatus, who tried to get laws passed in some States forbidding its use, and they went so far as to secure the use of a Westinghouse dynamo for the first electrocution plant, hoping thereby

to make it appear that the alternating current was essentially more deadly than direct current What a commentary on this action is the fact that all the great power plants to-day are using the alternating current!

The new form of current (in the sense that its practical application was later) had demonstrated its usefulness for lighting. It remained to develop a practical and simple motor so that it could be used for power, for the synchronous motor needed more skill for its attendance than could be given in the ordinary machine shop. Then came Tesla, who found in Mr. Westinghouse a friend and backer, whose faith did not weaken while the induction motor, Tesla's great invention, was perfected. This solved the problem of the transmission of power, for it gave a machine as simple as a grindstone and yet of the highest efficiency, and almost "fool-proof." At the present time the great majority of industrial plants using electricity for power are equipped with these motors.

What has been said would give some idea of Mr. Westinghouse's steadfastness under great discouragement, and the story of the lighting of the Chicago World's Fair is another illustration. He believed this a great opportunity to show what could be done by alternating current, and made a tender lower by a million dollars than any other bidder. Then his troubles began. Competitors made such charges as to his inability to carry out the contract that he was forced to give a bond for the full amount of the contract. Then he was enjoined from making the familiar glow lamp. He actually had to invent a new form of lamp, and to this he added a new air pump. Old employees tell, with much admiration, how, at this time, he worked day after day, in his shirt sleeves, perfecting the various details. But the lighting of the Fair was a great success, and, curiously enough, the only return to the stockholders of the Fair was the million dollars he had saved them.

The present works of the Westinghouse Electric & Manufacturing Company at East Pittsburgh were built in 1895, and consisted then chiefly of two main buildings 750 feet long, one 230 feet wide, and the other, 100. There was an almost universal opinion that the buildings were too large ever to be filled with work. So far from sharing this view, Mr. Westinghouse located them so that they could be extended at both ends, and with enough room at the side to duplicate them. In 1899 they were extended at one end; in 1900 at the other; in 1901 the space between was turned into another bay 1200 feet long. Now, in 1902, the duplication of this already huge plant is in progress.

It might seem that the work thus far mentioned would be more than enough to keep one man busy; but meanwhile this tireless man developed and exploited the use of natural gas in the Pittsburgh district, selling out his interest after the undertaking had been fully developed and made a success. To show what could be done in electric lighting with alternating current, he organised the United Electric Light & Power Company in New York, the Allegheny County Light Company in Pittsburgh, and another in Baltimore. After these had all been made successful, he withdrew from them to be able to give more attention to his other great undertakings. While out of the chronological sequence, it may be mentioned here that, under his guidance and at his expense, the Nernst lamp has been made a commercially successful article. He is also the backer of Mr. Peter Cooper Hewitt in the development of the mercury vapour lamp.

Besides the plants already mentioned, there are the great shops of the Westinghouse Machine Company, at East Pittsburgh, for building steam and gas engines and steam turbines, of which Mr. Westinghouse is principal owner; and there have been for years works for making air brakes in England, France, and Germany, while electric works were established at Havre in 1898. The most important of the works outside of the United States is the great plant of the British Westinghouse Electric & Manufacturing Company, at Manchester, which is almost a duplicate of the works at East Pittsburgh. These

works have attracted marked attention from their size and from the rapidity with which they have been erected.

Long as this list is, we have not mentioned all the works, for there are foundries at Cleveland and Allegheny, with new ones of great size in course of erection at Trafford City, a few miles from East Pittsburgh, and works in Newark, New York, and Pittsburgh. There is also a Russian Westinghouse Company for handling the products of the various factories. It is estimated that the various works and companies which bear his name represent a capitalisation of about seventy-five million dollars, and give employment to more than twenty thousand people.

This sketch has attempted to show that the success of Mr. Westinghouse has been due to his own talents, industry, prevision, and courage. It has not been a case of good luck; indeed, at a number of stages in his career luck seemed to be decidedly against him. There was once a time when his friends had all concluded that he must go under and sacrifice his fortune, which even then was counted with seven figures; but even this did not daunt him, and his ability as a financier enabled him to reorganise so as to go on to the great success of to-day. He has never countenanced stock watering or schemes of that kind, and to-day the capital of all his properties represents actual value.

He is a man of very attractive personality and charm of manner, and entertains handsomely in his homes at Pittsburgh, Washington, and Lenox. He is withal a very modest man, entirely averse to personal publicity, and this is the first time that a really satisfactory portrait of him has been published. If his wishes had prevailed, this sketch would not have appeared; but he has yielded to the earnest solicitio of the editor, who wished to gratify th public desire to know something of the personality of the man whose work has made his name a household word to the engineering world.

His devotion to work does not leave him a great deal of time for social pleasures, so that the hospitality of their beautiful houses is mainly dispensed by Mrs. Westinghouse, a gracious lady who is an ideal hostess, as is testified by the many who have been her guests. They have one son, George Westinghouse, Jr., who is now a student at Yale University. Mr. Westinghouse has the decorations of several foreign orders, including the Legion of Honour, and the Royal Crown of Italy. At the last meeting of the American Association for the Advancement of Science he was elected an honorary member on account of the great benefit of his work to the cause of science. This is an honour rarely conferred, and there is only one other American honorary member living.

It is very difficult, particularly for an officer of one of his companies, in writing about such a man to tell the story of his life so that it will be free from all appearance of flattery and exaggeration. The fact is that he is a wonderful man, who has done so many remarkable things that the simple truth, as it has been given here, seems extraordinary. Those who know him best will, however, appreciate how much more there is to tell. This at least is certain, that he has made an indelible impression on the industrial world, and his work justly entitles him to rank with Watt and Stephenson and Morse and Whitney and the other great inventors high up in the list of those who have benefited mankind.

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ELECTRIC POWER IN INDIA

THE CAUVERY FALLS PLANT

By Captain J. H. Thomson

NOT among the least, perhaps, of the many natural advantages possessed by the enlightened and progressive State of Mysore are the opportunities afforded for the development of water power, notably by the magnificent falls of Gersoppa and those of the Cauvery at Sivasamudram, which latter are situated on the southern boundary of Mysore territory and within 50 miles of the capital of the State.

The Cauvery is one of the principal rivers of Southern India. Rising in Coorg, among the Western Ghauts, and receiving six large tributaries in its course of 160 miles through Mysore territory, it drains an area computed at nearly 6400 square miles before reaching the picturesque gorge in which the falls are situated. There the river divides, forming the island of Sivasamudram, this being about three miles in length, and three-quarters of a mile in width, the falls, which are known as the "Burra Chukki," and the "Gangan Chukki," being located in the east and west branches of the river, respectively, about half a mile from the north or down stream end of the island. Beyond a few old Brahmin temples, the island of Sivasamudram and the immediate vicinity contain nothing of special interest, if we except the two extraordinary primitive old stone bridges, the larger of which, across the western branch of the river, is about 2000 feet in length. These structures consist of rough stone pillars, supporting a roadway on equally rough stone slabs, the whole meandering across the river, in very tortuous fashion, the general effect being in perfect harmony with the rocky river bed and the ruggedness of the surroundings.

Sivasamudram has, unfortunately, an unenviable reputation as being very malarious during the spring months, and the cultivation is confined to some 130 acres of paddy on the island, the population being exceedingly sparse. A good road from Maddur, a station on the Mysore State Railway, half way between Bangalore and Mysore City, runs through Sivasamudram (28 miles) to Kollegal (40 miles) in the Coimbatore District of Madras.

The utilisation of the power afforded by the Cauvery Falls was from time to time discussed for several years prior to 1899; but there being no ap-

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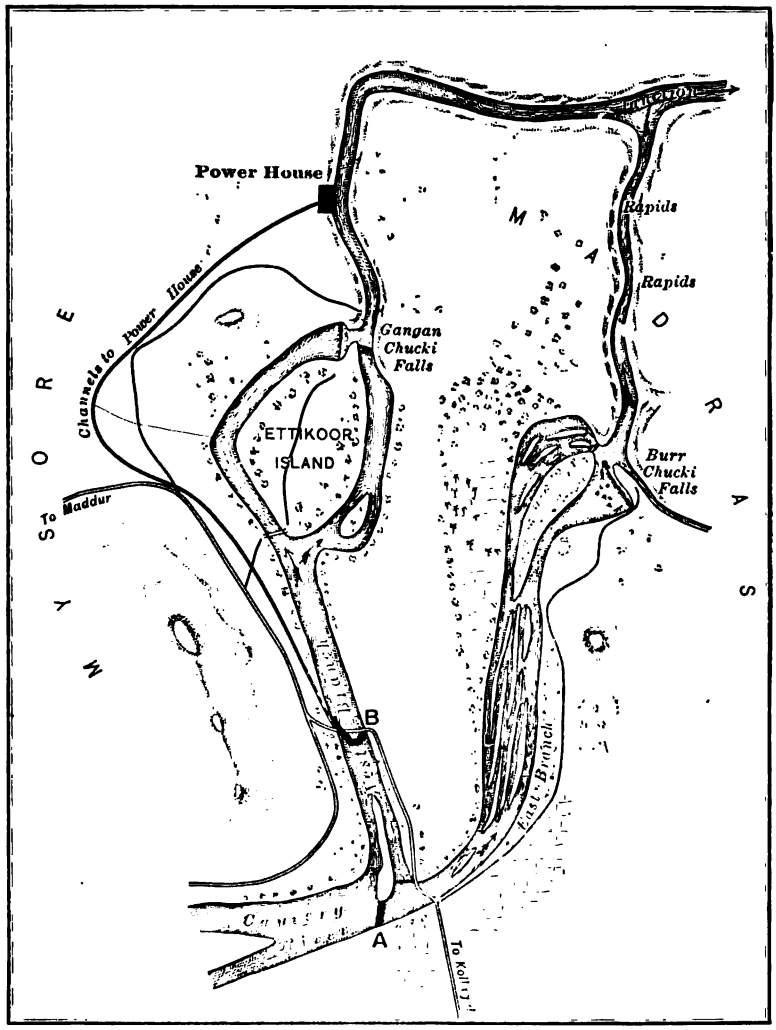
A VIEW OF THE POWER STATION, PENSTOCKS, AND TRANSFORMER HOUSE

parent local market for it, and no prospect of any large manufacturing industries being established in the district, were cheap power made available, the various ideas put forward never got much beyond the stage of conjecture. In 1894-5, however, the Mysore Government constructed a series of temporary gauging dams in the Cauvery at Sivasamudram with a view to testing the capabilities of the river under minimum conditions, and to the possible development of water power. These gauging operations cannot be said to have been altogether satisfactory, as regards accuracy, but were sufficiently convincing to warrant the belief that constant water power on a fairly large scale could be established and maintained at Sivasamudram. Meanwhile, enormous strides and remarkable developments in the long-distance transmission of electrical power were being made, especially in America, and by the further researches and discoveries that had been made regarding the properties and capabilities of the multiphase alternating current system, distance, it may almost be said, was being practically annihilated. Commencing at the beginning of the last decade with the magnificent Niagara scheme (which may be considered as the pioneer of great enterprises of the nature under discussion),

the distance to which power on a large scale had been successfully transmitted, from the source of generation, had jumped from less than 30 miles in 1890 to over 80 miles in 1900.

These developments had not escaped the attention of engineers in India, and de Lotbinière, R. E., Deputy Chief Engineer to the Government of Mysore, and the scheme immediately met with the cordial sympathy and support of Col. D. McNeil Campbell, R. E., the Chief Engineer, and the late lamented Sir K. Sheshadri Iyer, the Dewan of



GENERAL PLAN OF THE HEAD WORKS. THE UPPER DAM IS MARKED *A*, AND THE LOWER DAM *B*

in June, 1899, the idea of working the Kolar Gold Mines, distant 92 miles from Sivasamudram, with electrical power, generated by the waterfalls there, was conceived by Captain A. J. Mysore, whose death before the completion of this great work, in which he took such keen interest, will always be most deeply regretted. His able successor, P. N. Krishna Murti, C. I. E., has,

THE CAUVERY RIVER IN FLOOD TIME. THE HEAD WORKS OF THE POWER PLANT ARE SHOWN AT THE LEFT. THE BRIDGE IS ONE OF TWO OLD STONE STRUCTURES OF PRIMITIVE DESIGN AND ABOUT 150 YEARS OLD

however, been in no way behindhand in futhering the undertaking. The Honourable Col. D. Robertson, British Resident in Mysore, lent his hearty support and assistance in carrying through the necessary negotiations with the governments of India and Madras, and continued his keen interest in the work throughout its construction.

Preliminary investigations, thorough and reliable river gauging, and the preparation of an approximate estimate of cost of the project, were immediately put in hand. Three alternative schemes for river works and channels, etc., were considered, and the layout finally adopted for this portion of the project was that selected by Col. D. McNeil Campbell and Mr. W. H. McHutchin, Superintending Engineer, Western Circle. Meanwhile, negotiations with the managing directors of the various gold mining companies were being conducted with every prospect of success, and the scheme in due course received the assent and sanction of His Excellency the Viceroy of India, Lord Curzon. The questions of water rights, etc., as between the Madras and Mysore governments, the common boundary between the respective territories being the centre of the Cauvery River at Sivasamudram, (western branch) were also under discussion and representation, and well advanced towards satisfactory settlement.

In August, 1899, the Mysore Government deputed Capt. de Lotbinière to Europe and America for the purpose of obtaining the opinion of a committee of experts, and to arrange for tenders from the leading manufacturers of hydraulic and electrical plant, after carrying to a final issue the negotiations with the gold mining companies already referred to, and completing agreements for the supply of power, which, it had now been settled, should be fixed, in the first instance, at 4000 H. P. delivered on the gold fields, for a period of ten years. The deputation was attended with most satisfactory results, very rapidly achieved. By August,

THE CHANNELS TO THE POWER HOUSE IN ORDINARY EARTH CUTTING

LOWERING A PENSTOCK DOWN THE BLUFF

1900, the agreements with the mining companies had been formally ratified and signed, and contracts had been let to the General Electric Company, of New York, and Messrs. Escher, Wyss & Co., of Zürich, for the supply and erection of the electric and hydraulic plant, respectively, all details having been scrutinised by Professors Unwin and Forbes, who, together with the writer, formed the committee of experts already alluded to. The writer was also appointed Secretary and Consulting Engineer to the scheme in London. The penstock pipes were ordered through Messrs. Escher, Wyss & Co. from Messrs. Mechan & Sons, of Scotstown, Glasgow. The firms to which the manufacture of the plant had been entrusted are, it should be stated, among the foremost in the world engaged in this special business.

The preliminary project relating to works to be carried out in India having been sanctioned, a special "Cauvery Power Scheme Division" was formed, a temporary camp opened at Rottikatty, one and a half miles from the works,

and ground was broken on the excavation of the supply channels on August 10, 1900.

Capt. de Lotbinière, since returning to India in February, had been meanwhile busily engaged in preparing details of the plant required on the gold fields, for the distribution of the power there to the various mining companies, and at the end of July, 1900, he left again for America, with all the necessary data, to arrange for the supply of this portion of the machinery.

The Cauvery Power Scheme Division, in charge of Lieutenant J. C. Hunter as Resident Engineer, comprised four subdivisions, for distribution of work as here given:—

No. I Sub-Division.—River works and upper half of channels.

No. II Sub-Division.—Lower half of channels, Quarters for Staff and Power Station buildings.

No. III Sub-Division.—Main Transmission Line, Sivasamudram to Kolar Gold Fields, 92 miles.

No. IV Sub-Division.—Distribution buildings and line work on the Kolar Gold Fields.

The engineering staff of the Mysore Service (P. W. D.) was made up of Colonel D. McNeil Campbell, Chief Engineer of Mysore; Captain A. Joly de Lotbinière, R. E., Deputy and Superintending Engineer; Lieutenant J. C. Hunter, Resident Engineer; Mr. J. Bhore, Assistant Engineer, Personal Assistant to Resident Engineer; Mr. J. E. A. D'Cruz, Assistant Engineer, No. I Sub-Division; Mr. C. Madava Row, Assistant Engineer, No. II Sub-Division; Mr. K. Sreenivasa Iyengar, Assistant Engineer, No. III Sub-Division; Mr. F. A. Steele, Assistant Engineer, No. IV Sub-Division; Mr. H. D. Rice, Assistant Engineer, Superintendent of Road and Transport (subsequently to charge of No. III Sub-Division).

The Cauvery was in a very high flood when operations were commenced, and a vigorous start was made upon the excavation of the channels and quarters,

A VIEW OF THE THREE PENSTOCKS LEADING DOWN TO THE POWER HOUSE, AND OF THE CABLE CONDUIT. EACH PENSTOCK IS 930 FEET LONG AND RANGES FROM 36 TO 45 INCHES IN DIAMETER

THE TRANSMISSION LINES CROSSING A RIVER. AT SUCH CROSSING POINTS THE THREE WIRES OF EACH LINE ARE SPREAD OUT HORIZONTALLY, 10 FEET APART, INSTEAD OF FORMING EQUILATERAL TRIANGLES AS SHOWN ON PAGE 394

both permanent and temporary, on the bluff for the accommodation of the engineering and office establishments. The first check to progress occurred within two months of starting, when an outbreak of cholera, lasting three weeks, caused an almost complete cessation of operations for nearly a month.

Practically the whole of the labour for these works had necessarily to be imported, there being no local resources in this respect in the thinly populated surroundings of Sivasamudram, where the people are cultivators. During the last quarter of 1900 and the first six months of 1901 the imported labour could not have fallen far short of 5000 men. A well-equipped dispensary was established on the commencement of work, and the labour camps were well taken care of from a sanitary point of view.

The difficulties in regard to labour were, however, counterbalanced, in no small degree, by the superabundance of very excellent building material, in the hard and durable bluestone boulders (a kind of trap), with which the slopes of the river valley are strewn. All the masonry works at Sivasamudram have been built of this stone, supplemented with slabs of granite and gneiss, from local quarries within a radius of fourteen miles. First-class Kunkur limestone was also abundantly procurable from local sources at all times, and bricks, together with soorkhee, were manufactured, and lime was burnt at the site of the works. By the end of the year good progress had been made on the channels, and the river had fallen sufficiently to enable a start to be made upon the dams. The General Electric Company had meanwhile undertaken the supply of the distribution plant, and this contract had been duly signed at the end of September. It should be noted that the contracts for the supply of the machinery, both hydraulic and electric, included erection and maintenance for a period of twelve months in every case. The first party of the General Electric Company's engineers and employees arrived in India just before Christmas, 1900, the

remainder following at intervals during 1901, as their services were required.

The following comprised the staff for erection and maintenance of the combined plant:—General Electric Company, New York. Mr. Axel Ekstrom, Chief Electrical Engineer; Mr. A. C. Jewett, Electrical Engineer, Personal Assistant to Chief Electrical Engineer; Mr. H. Footman, Secretary; Mr. E. L. Cullen, Electrical Engineer, with three assistants (Erection of Generating Plant); Mr. S. Huston, Electrical Engineer, with four assistants (Erection of Transmission Line, 92 miles); Mr. H. Gibbs, Electrical Engineer, with three assistants (Erection of Distribution Plant at the Kolar Gold Fields).

Messrs. Escher, Wyss & Co., Zürich. Mr. W. Muller, Chief Erector, with one assistant erector, and two men from Glasgow, for the laying of the penstocks. The hydraulic plant was built and erected after the plans of Mr. Alph. Steiger, M. Inst. C. E., who is the representative of Messrs. Escher, Wyss & Co.

The first shipment of line material arrived at Mormugao (where all the plant from America and Europe, except penstock pipes from Glasgow, was landed) in January, 1901, and the final survey of the line, jungle clearing, and other preliminary operations through the country to be traversed (in many parts very rugged and difficult) were at once commenced. A central depot near the Bangalore City Station was established, where all material was received, verified and distributed by rail or road, to the various points of the system. The camp at Rottikatty had meanwhile been struck, and the divisional headquarters established on the bluff, immediately above the site of the forebay and power station, where the buildings for accommodation of the staff (over eighty in number) formed quite a little colony. A pumped and filtered water supply had been early installed, and a branch post office established, together with a regular tonga service between Maddur and Sivasamudram, the latter being subsidised by the Mysore Govèrnment for three years. A general provision store was also opened on the bluff, and temporary telephonic communication with Bangalore pending construction of the permanent system conjointly with the main transmission line very shortly fol-

H. H. THE MAHARAJAH OF MYSORE

SIR K. SHESHADRI IYER, LATE DEWAN OF MYSORE

THE FOREBAY, LOOKING TOWARDS THE PENSTOCK CHAMBERS. THE TRANSFORMER HOUSE IS SHOWN ON THE RIGHT. THERE THE VOLTAGE IS RAISED FROM 2200 TO 30,000 BY MEANS OF TWELVE STATIC TRANSFORMERS

lowed. A fairly self-contained little settlement thus existed among the wilds of Sivasamudram on the bluff overlooking the rapids just below the western falls, where but a few months before the foot of man had hardly trodden, and the inhospitable, albeit picturesque country, for miles around, afforded shelter only for the usual denizens of the jungle. The exact sites for the power house, forebay, and step-up transformer station had been finally selected; a material tramway on

THE CHANNELS APPROACHING THE FOREBAY. THE TOTAL LENGTH OF THE CHANNELS, FROM HEADWORKS TO FOREBAY, IS A LITTLE OVER THREE MILES

the balance principle had been completed down the face of the bluff, and foundations were well in hand at the beginning of March, 1901, when a commencement was also made with the step-down transformer station, compressor houses, motor sheds and other buildings required on the Kolar Gold Fields for the housing of the distribution plant. Inspection lodges, patrol huts, and necessary buildings at two intermediate stations on the transmission line were also put in hand at this time. The two intermediate points on the line where maintenance gangs and material will be permanently located, divide the whole length of 92 miles into three sections of about 30 miles each.

It should be noted with reference to the step-up transformer station that in this scheme an important departure from accepted practice has been made, for, whereas the transformers are invariably located either under the same roof as the generators, or in a building very closely adjacent, the transformer station at Sivasamudram has been erected on the flank of the forebay 400 feet above, and 900 feet from the power house, the connecting cables being laid in a masonry conduit or duct (accessible from end to end at all times) running down the face of the bluff between the two buildings. This innovation was made to enable the whole of the electrical plant in the power house being controlled by the operators on duty in the transformer station, 400 feet above, thereby giving them the benefit of the more salubrious and airy conditions of the higher level. By June all the copper wire (about 500

HAULING HEAVY MACHINERY TO THE POWER HOUSE

tons) for the main and distribution transmission lines had been received in India, and the erection of poles on the main line, commencing from the Kolar end, had begun, the first pole having been erected on May 29, 1901.

The road transport of the heavy machinery over the 28 miles of undulating road between Maddur and Sivasamudram was rather an arduous business, and, unfortunately, had to be carried on during the wettest months of the monsoon (July to October), when the roads were heaviest. Special road trollies had been imported for the conveyance of the heaviest pieces (six to eight tons), and in the absence of traction engines eight huge state elephants from Mysore did yeomen's service in assisting the bullock teams with the work. By the middle of October the last piece of the heavy generating plant had been safely delivered on the bluff, and a month later saw the whole successfully lowered to the site of the power house.

The earliest shipments of the steel penstock pipes had meanwhile also arrived, these coming out in lengths of 10 feet (diameters being 36 inches to 45 inches), and gangs of men were busily engaged in riveting them up, in 30 and 40-foot lengths, ready for launching down the hill to their ultimate positions. The first week in December saw the whole of the hydraulic plant in the power house and a fair start made upon its erection, while by Christmas the transformer station at either end of the line had been roofed in, and the heavy transformers had been safely placed on their seatings. By the end of January, 1902, sufficient progress had been made on the erection of the hydraulic plant to enable the electrical engineers to gain admittance to the power house with their machinery, on the installation of which a start was made on the first of February, at the end of which month the line erecting party reached Sivasamudram and completed their work of constructing the double transmission line, over 92 miles of country between Sivasamudram and the Kolar Gold Fields.

A second outbreak of cholera occurred about this time in the cooly camps and hampered progress considerably. This was followed by plague that had been imported from the adjacent districts of Kollegal and Malvalli.

BOTH ELEPHANTS AND WATER BUFFALOS HELP TO HAUL THE LOADS

In both cases, fortunately, the outbreaks at Sivasamudram were short-lived, and the mortality was not heavy.

Early in March the laying of the penstocks, of which there are three down, or rather up, the face of the bluff, was commenced, and this heavy work, prosecuted day and night, occupied three months, the last rivet being closed on May 31. Meanwhile the two supply channels (3⅓ miles in length) had been completed and tested as regards discharge, etc., with most satisfactory results.

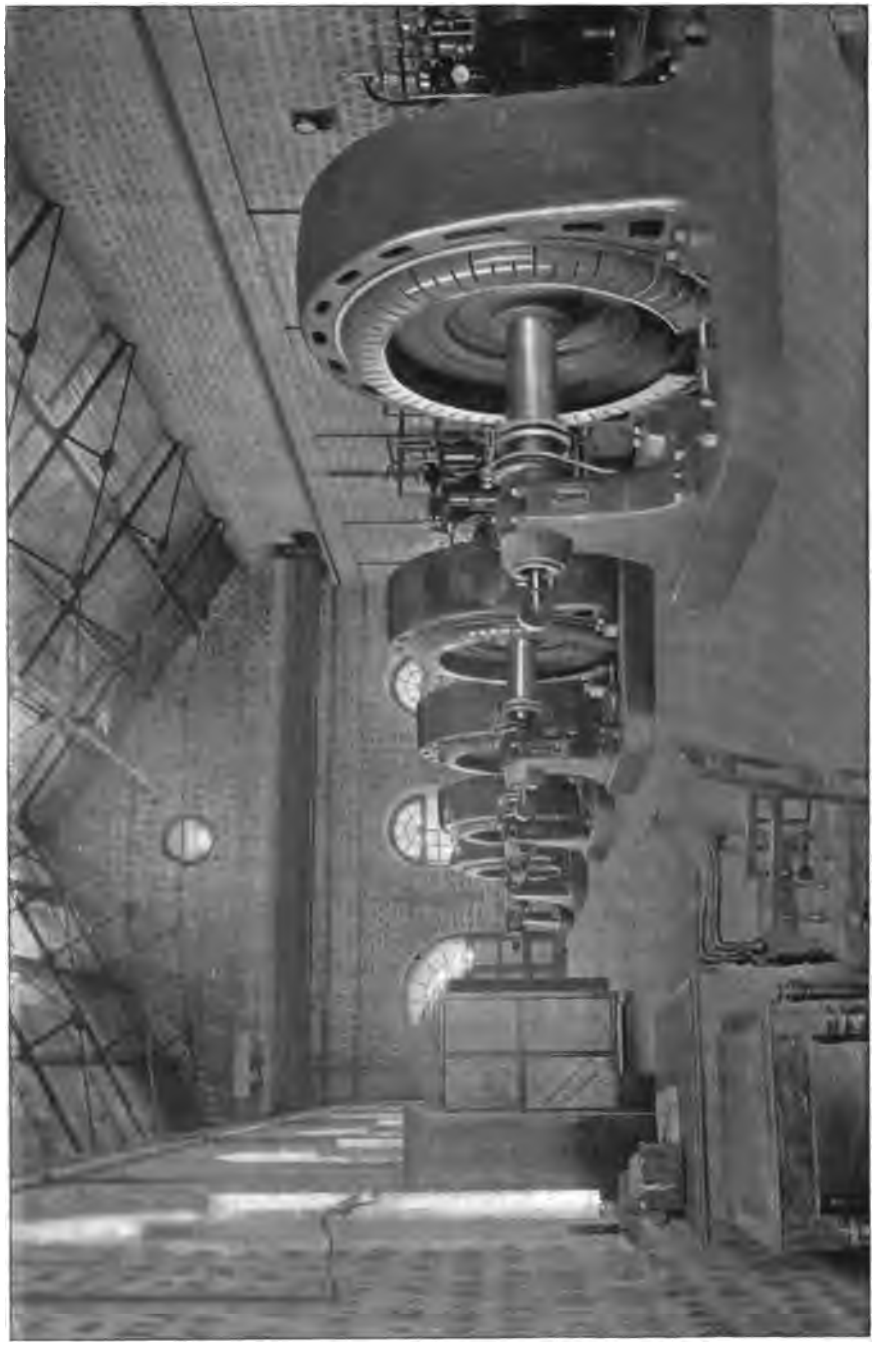
The whole of the plant for generation, transmission and distribution, together with the buildings containing it, was complete and ready in all respects at the beginning of June, 1902, and on the ninth of that month water was first admitted to the penstocks and passed through the power house. The testing and calking of pipes, with preliminary trial runs of the machinery for first tests, etc., occupied about two weeks, and at the end of June all was in readiness for the final testing operations.

On June 30 the Honourable British Resident in Mysore, Colonel Donald Robertson, and party visited Sivasamudram, and electric power was for the first time transmitted thence to the Kolar Gold Fields, the switch being closed by Mrs. Robertson, in the presence of the assembled visitors. Commercial service commenced on July 15, and has since been uninterruptedly maintained.

It may be of interest to note the various countries that have been drawn upon for this scheme, towards which the four quarters of the globe may be said to have been laid under contribution. The distribution of contracts was as follows:—Electric plant, United States of America. Hydraulic plant, Switzerland. Penstock pipes, Scotland. Insulators, Italy. Timber for the transmission line, Australia.* The timber used was the well-known Australian redwood, "Jarrah."

A brief general description of the whole scheme will now be given. The river works above the intake comprise two low-level diverting dams, of which the upper is located at the southern end of the island of Sivasamudram (where

* A combined pole was used on the lines, 17 ft. of 7-inch timber, in 13 ft. of steel socket, the latter being 6 ft. in and 7 ft. out of the ground.



THE POWER HOUSE INTERIOR. THERE ARE SIX 1000 H. P. THREE-PHASE GENERATORS, EACH DIRECT-CONNECTED TO AN IMPULSE WHEEL

the river divides), extending across the eastern branch, and diverting the dry-season discharge into the western stream, whence the lower dam thrown across this branch diverts the water into a draught channel leading to the sluice gates at the head of the supply channels.

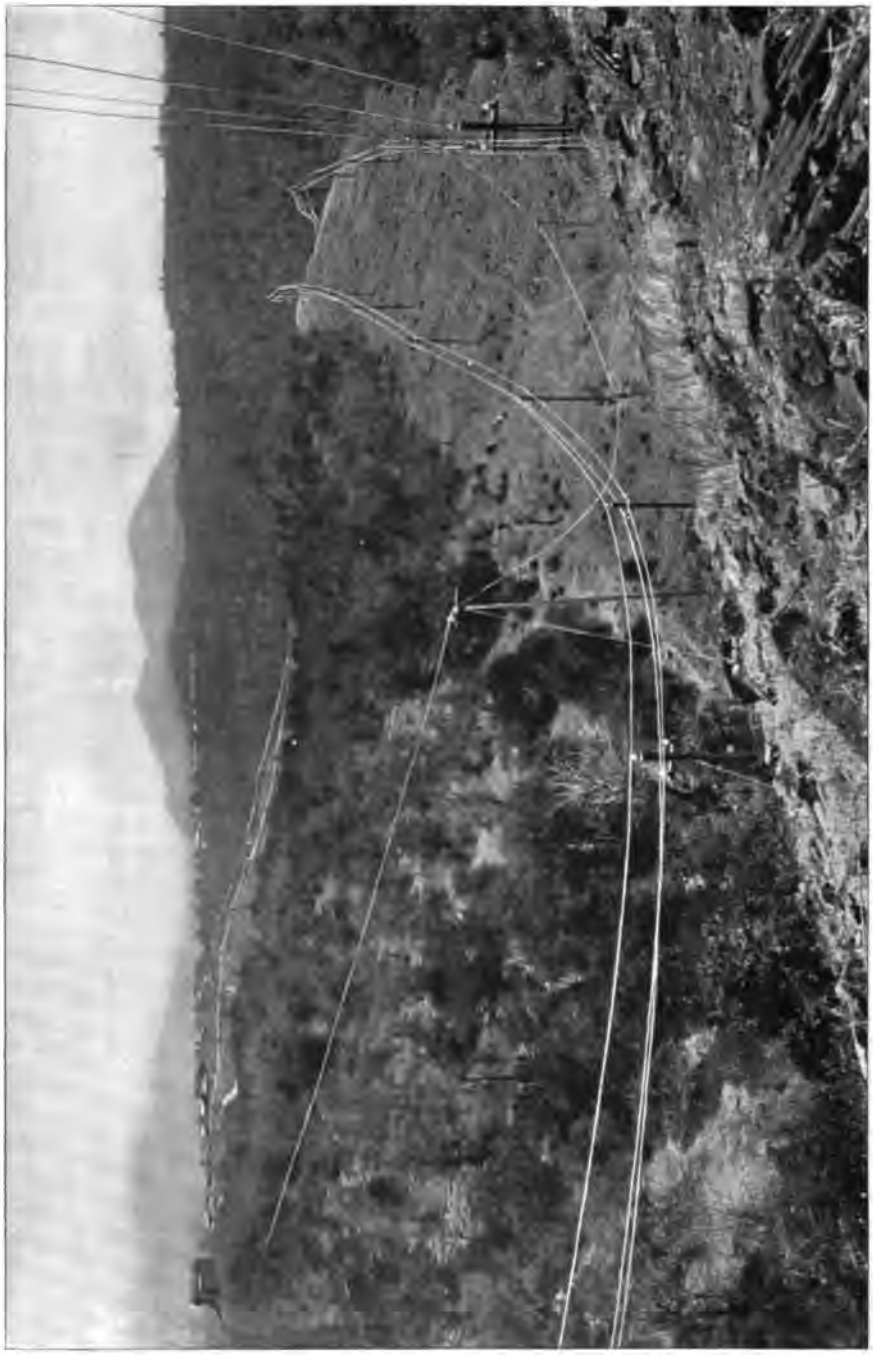
The head sluice, or intake, situated just below the left abutment of the old bridge at Sivasamudram, about 2 miles above the falls, contains eight vents, 4½ feet × 5 feet, four in each channel, with righting shutters, and is flanked by a scouring sluice having four vents of similar dimensions. The channels, which are double, each being of full capacity, are 3⅓ miles in length and run parallel throughout, the partition or dividing earth bank being 26 feet wide at the base and 10 feet on top.

The grades of the channels are $\frac{1}{5000}$ for earth, and $\frac{3}{5000}$ for rock sections, the bed widths being 18 feet and 12 feet, respectively, with stone-pitched side slopes of ¼. The normal depth of water is 5 feet and the calculated discharge per channel, 250 cubic feet per second. The trials made at the end of May, 1902, however, showed the capacity of the new channels (under minimum conditions, as regards initial head at the intake) to be fully 50 per cent. above that assumed from the calculations previously made. Ample provision has been allowed in the way of aqueducts, under which the surface drainage is carried, and also escape weirs in the banks, to meet emergencies. On the third mile the channels run through intervening high ground that entailed heavy cutting, from 28 feet to 34 feet in depth, for a length of 1200 feet in hard blue rock. Here the partition between the channels is formed by a wall of rubble masonry, the sides of the cutting being also vertical. The quantity of dynamite expended in blasting operations on this section alone was nearly eight tons.

The forebay at the tail end of the channels, flanked by the lofty and imposing transformer station, a landmark for miles around, is situated on the brow of the bluff, about half a mile below the western or "Gangan Chukki" falls, and opposite the northern end of the island of Sivasamudram. A separate chamber, with double geared gate, contains a valve at the head of each of the three penstocks, arranged to close automatically should the penstock burst; and clear water for the governor mechanism at the water-wheels is supplied by a separate 10-inch pipe, from settling tanks in the left front corner of the forebay.

Iron grids intercept all leaves and other floatable matter which have fallen into the water during its three-mile course down the channel. An escape weir, 100 feet long, on the left flank takes care of all surplus water reaching the forebay, and full provision has been made for scouring and for the removal of silt, etc. The three penstock pipes, conveying the water from the forebay to the power house 400 feet below, are of riveted steel plate, ¼ inch to ½ inch in thickness, and 45 inches in diameter at the upper end and 36 inches at the lower, the length of each down the face of the bluff being about 930 feet. Expansion joints and anchorages are provided at three points on the steep hillside, the pipes, which are above ground for about four-fifths of their total length, being carried on substantial masonry piers 15 feet apart. On entering the power house each penstock bifurcates, serving two water-wheels, to each of which is coupled direct a generator of 1000 H. P.

The makers' guarantee for the turbines is 1250 brake H. P. at the coupling, with 37 cubic feet of water per second, the effective head at the wheel being 382½ feet. There are thus six 1000 H. P. units of combined water-wheel and generator in the power house. The water-wheels are of the impulse type, 60 inches in diameter, with a governor of special and improved construction, with a guaranteed efficiency of 75 per cent. for full gate, and 70 per cent. for half gate. The governors are to maintain normal speed constant within 2 per cent. for sudden variation of load of 10 per cent; within 4 per cent. for sudden variation of load of 25 per cent.; and within 8 per cent. for sudden variation of load of 50 per cent. The governors are fitted with pressure regulators



THE TRANSMISSION LINES TO THE KOLAR GOLD FIELDS, 92 MILES DISTANT, ARE ARRANGED IN THE SHAPE OF EQUILATERAL TRIANGLES

to maintain the water pressure in the pipes constant, within 5 per cent. of normal, under sudden variations of load.

The generators are three-phase alternators, with a revolving field, and stationary armature. The rated output is 720 KW, the frequency is 25 cycles, the speed being 300 revolutions per minute, and the voltage 2200. The excitation for the fields of the alternators is supplied from two independent 75 KW exciters, separately driven by two small turbines of type identical with the main wheels, the speed being 465 revolutions per minute. Each exciter is capable of supplying the exciting current of all six generators. The cables conducting the current from the power house are carried on stone shelves, within an enclosed masonry passage or duct, up the face of the bluff to the transformer station where the voltage is raised from 2200 to the line potential of 30,000 by means of static transformers. These are twelve in number, each of 400 KW capacity, in four banks of three, one of which forms the reserve. Air blast for cooling is supplied by electrically-driven, direct-coupled blowers through an air chamber immediately under the transformers. A similarly driven air compressor in each of the two main buildings, with receiver and distribution system, furnishing air at sixty pounds pressure for blowing dust out of the apparatus, completes, with the lighting systems, the installation of the generating and transmitting plant at Sivasamudram.

The transmission to Kolar is effected by two parallel lines 60 feet apart. The three wires (No. 0 B. and S. gauge) on each line form an equilateral triangle with 40-inch sides, the upper insulator being carried on top of the pole, and the two lower ones by a cross-arm. The poles, a description of which has already been given, are spaced at 130 feet along the line, and the minimum height of the lower wires above ground is about 20 feet. The maximum length of span at river crossings is 525 feet, and in all these cases the wires are spread out horizontally, 10 feet apart, and are carried on special pole structures, cable of silicon-bronze being substituted for the ordinary copper wire. This latter precaution is also adopted in crossing railways and the government telegraph lines. The telephone wires are carried on one line by a separate small cross-arm, placed 6 feet below the main wires. Transposition of the main line wires is made three times in the total length of 92 miles, and in the case of the telephone circuit at every fifth pole. Ordinarily, both lines will be used for transmission, each carrying half the current. Either, however, has capacity sufficient to transmit the full power at increased potential, to meet emergencies in the way of repairs.

On reaching Kolar, the wires enter the transformer station, a handsome building, occupying a conspicuous and central position on the field, where the voltage is reduced to 2300 by means of twelve step-down transformers, arranged and cooled as at the generating end. All motors on the field over 100 H. P. work at this voltage of 2300, which is reduced to 220 for those of less power, by means of transformers at the motors. By far the greater portion of the power supplied to the gold fields is absorbed by air compressors for the underground pneumatic drilling and other work, and by the quartz crushing mills at the surface. There are in all thirty-one motors installed on the gold fields, ranging from 5 to 400 H. P., the average being 133 H. P. Of these, the three of greatest capacity, viz., two of 300 H. P. and one of 400 H. P., are synchronous motors, all the remainder being of the induction type. Eleven new electrically-driven air compressors have also been installed at Kolar. These range from 150 to 400 H. P., and were manufactured by the Ingersoll-Sergeant Drill Company, of New York. The distribution plant comprises the following:—

					Total H. P.
8	Motors	induction type	each ... 200	H. P. =	1,600
8	"	"	... 150	" =	1,200
2	"	"	... 100	" =	200
2	"	"	... 40	" =	80
1	"	"	... 30	" =	30
3	"	"	... 15	" =	45
2	"	"	... 10	" =	20
2	"	"	... 5	" =	10
1	"	synchronous	... 400	" =	400
2	"	"	... 300	" =	600
31				Total H. P. =	4,185

NEW ELECTRICALLY-DRIVEN AIR COMPRESSORS.

For 400 H. P. Motor	1
" 300 "	1
" 200 "	4
" 150 "	5
Total No	11

Five hoists and a pump, in addition to the foregoing, complete the distribution machinery. A fully equipped electrically-driven modern machine shop has been installed on the gold fields, close to the transformer station, wherein all repairs can be promptly and effectually carried out. The main and feeder lines on the distribution system, over the various mines, comprise about 25 miles of wiring, the gauge of which varies from No. 0 to No. 0000 B. & S. The following are the mining companies to which power is being supplied:—

Mysore.	Coromandel.
Champion Reefs.	Balaghat.
Ooregaum.	Gold Fields.
Nundydroog.	Nine Reefs.
Oriental.	Road Block.

The extent of the above field over which the motors are distributed is about six miles in length by one mile in width. It may be noted that the total loss in transmission between the generators at the one end and the motors at the other end of the system is approximately 20 per cent., an output of nearly 5000 H. P. at the power station being requisite for the delivery of 4000 H. P. at the Kolar Gold Fields.

The cost of the scheme, as far as can be foreseen at the time of writing, will be approximately as follows:—

Hydraulic plant	£26,500
Electrical plant, generating and transmission	112,000
Distribution plant	53,000
Works in India; Rs. 22,29,000	148,600
Total	£340,100

The present agreement with the mining companies concerned, as already stated, is for the supply of 4000 H. P. (full time) for a period of ten years. The rate per H. P. per annum varies during the first five years from £18 to £29, the average being £20-4.

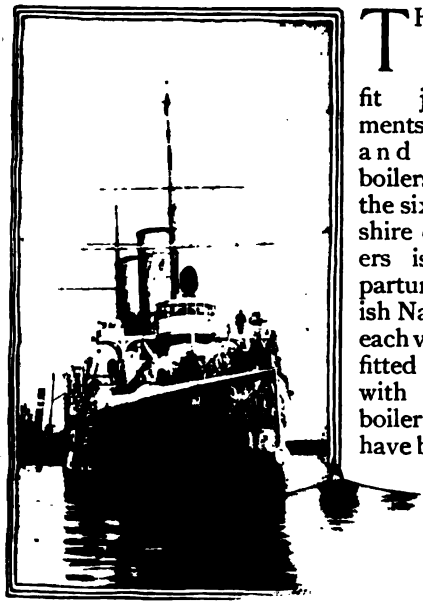
For the second five years a uniform rate of £10 per H. P. is to be paid by the mines. On this basis, after making full provision for working expenses and depreciation, it has been calculated that the Mysore Government will recoup practically the whole capital outlay by the end of the sixth year, and obtain revenue equal to 10 per cent. thereon from the seventh to the tenth year, inclusive. It has also been established that the mining companies should save in working expenses well over half a million sterling during the ensuing decade. These figures bear eloquent testimony to the soundness of the financial basis upon which the project rests. It is expected that the present installation of 4000 H. P. will be doubled in the near future, the mines, under the existing agreement, having reserved the right to the whole of this increase to meet their ever increasing requirements. It has, however, at the same time been fully understood that the additional power may be liable to interruption for a week or two in exceptionally dry years owing to shortage of water.

Finally, it may be noted that the Cauvery power transmission is at once the largest scheme of its kind in the British Empire, and the pioneer, it may also be hoped, of future developments on similar lines in India. It will, furthermore, never be forgotten that to Mysore, and, in no small measure, to that illustrious statesman, the late Sir Seshadri Iyer, after whom the power station has been aptly named, will redound the credit of that bold spirit of enterprise and pertinacity which has successfully carried out within its own territories, and that upon no mean scale, one of the greatest and most recent developments of modern science from the Far West. At the time of writing, the full power has been in successful operation for nearly three months.

A NEW DEPARTURE IN BRITISH CRUISER MACHINERY

THE QUESTION OF WATER-TUBE BOILERS

By George Halliday



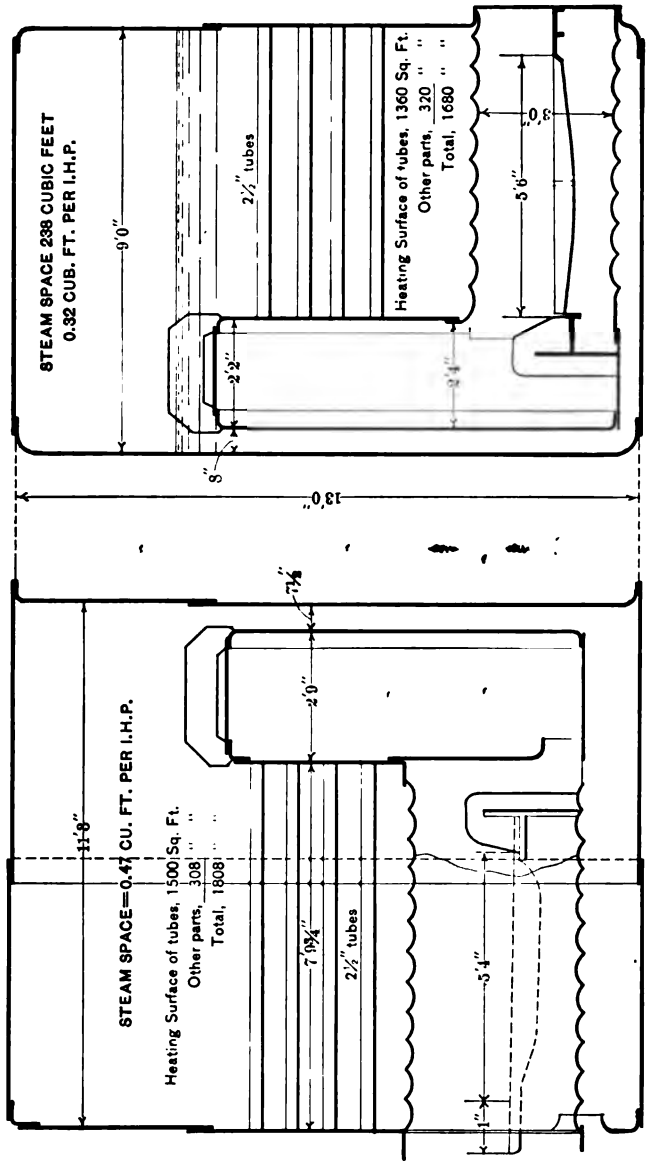
THE DUTCH CRUISER "ZEELAND" WITH YARROW BOILERS

THE decision of the British Admiralty to fit joint installments of cylindrical and water-tube boilers into each of the six new Devonshire class of cruisers is a new departure in the British Navy. Hitherto each vessel has been fitted throughout with one type of boiler. Either they have been all cylindrical, all Belleville, or all of some other type of water tube boiler. Now, however, it is proposed, or rather resolved, to fit boilers into the ships to suit both cruising speeds and high speeds.

For these particular cruisers the cruising speed, or easy rate, at which they may make ordinary voyages, lies between 12 and 13 knots, and it is intended to fit a sufficient number of cylindrical boilers into the ships to give them steam enough to make this speed. But in time of war it is intended that these ships should make higher speeds, reaching up to a maximum of 23 knots an hour, and accordingly the Admiralty have decided to fit them with water-tube boilers of capacity enough to supply the necessary steam to make the speed above the cruising rate when it is desired. The cylindrical boilers will thus always be at work. The water-tube boilers will be in action only when the exigencies of war require the higher speed to be made.

It is said that the boiler committee, composed of experts external to the Admiralty, recommended that these water-tube boiler installations in all the cruisers should be of the Yarrow type. Their reason, it is alleged, for doing this was that the other types had been fitted into vessels in sufficient numbers to enable the committee to come to a decision as to whether they should be fitted into further vessels of the Royal Navy. But the Admiralty have not agreed with the committee on this point. Nor have they even agreed with them as to what exact proportion of the total maximum power should be supplied by cylindrical boilers and what by water-tube boilers. The final decision of the Admiralty is that of the total maximum 22,000 horse-power in each ship 4500 horse-power are to be provided by cylindrical boilers for cruising purposes and the remainder by water-tube boilers for the higher speeds. The committee, it is said, recommended that 6000 horse-power should be provided by cylindrical boilers.

The cylindrical boilers are to be constructed to the Admiralty designs, and it is not out of the way to say that the proportions of the three which are to be fitted with forced draught are a little fanciful. The usual length of a single-ended marine boiler is about 10 feet 6 inches or 10 feet 8 inches; the tubes are 9 feet 9 inches long; the combustion



THE USUAL AND THE BRITISH NAVY DESIGNS FOR CYLINDRICAL BOILERS

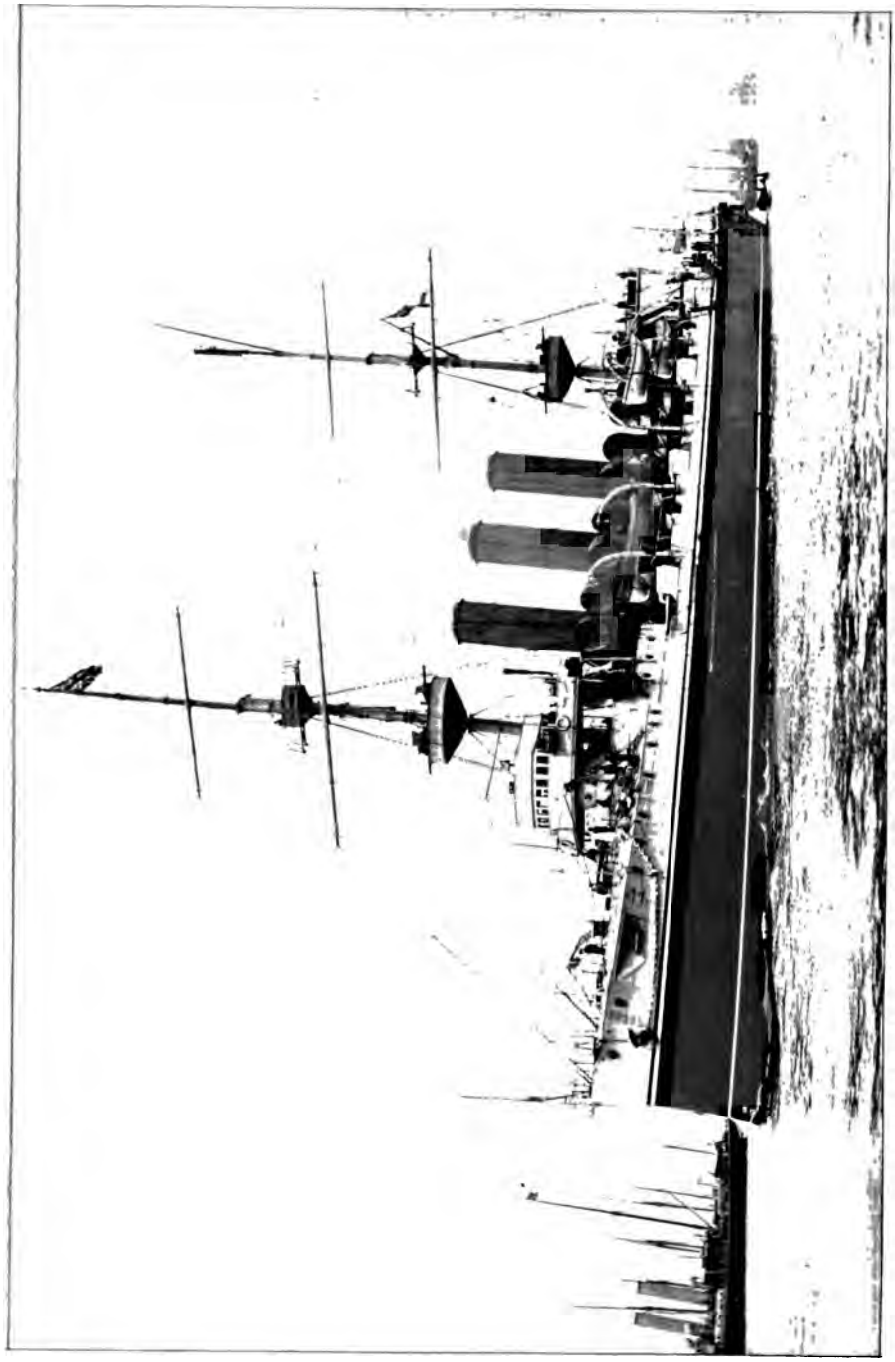
chamber is 3 feet 3 inches wide; and the water space about 6 inches. In the Devonshire cruiser class the boilers are to be 9 feet in length over all, that is, 6 feet 3 inches for the tubes, 2 feet 3 inches for the combustion chamber, and 6 inches for the water space. It seems assured that in these boilers, fitted with forced draught, there will be trouble in the combustion chambers and incomplete combustion of the gases. The boilers are to be 13 feet in diameter.

To make the comparison between the ordinary and the Navy designs still more clear, the two types of cylindrical boilers are shown side by side on the opposite page. The diameters of the boilers are the same, but they differ in every other paricular. In the left diagram, which shows the usual designs adopted for a forced draught boiler, the length is much greater than that considered sufficient for the same purpose by the Admiralty. In both cases the tubes are 2½ inches in diameter, but the length adopted in ordinary practice is 7 feet 9¾ inches, as against 6 feet 3 inches shown in the Admiralty design. Because of this the rapidly moving gases will be through the shorter tubes and will have reached the uptake before they have parted with much of their heat. The effect of this will be shown by a higher funnel temperature and a much higher consumption of coal per I. H. P. per hour.

Another difference is found in the position of the fire bridge. In the usual practice the bridge is well within the furnace. In the Admiralty design the bridge has been built at the back, outside the furnace. The effect of this extraordinary placing of the bridge in the Admiralty design will be to cause the hot gases to strike against the upper back end of the furnace and loosen the tubes at the back tube-plate. When these tubes are loosened in this way they soon leak and give endless trouble.

It is also to be noted that three furnaces have been fitted into the same size of shell instead of two, as in the usual practice, and that the diameter of each of the three is only 3 feet instead of 3 feet 8 inches. The whole success of forced draught depends on plenty of space being allowed above the fire so that there may be ample room for the products of combustion and the hot air which is ad-

THE "SAXONIA," OF THE CUNARD LINE, UNDER TRIAL IN CONNECTION WITH H M. S "HYACINTH" AND "MINERVA," SHOWN ON PAGES 400 AND 402, SO AS TO AFFORD A MERCHANT MARINE BASIS FOR COMPARISON



H. M. S. "HYACINTH." EQUIPPED WITH BELLEVILLE WATER-TUBE BOILERS

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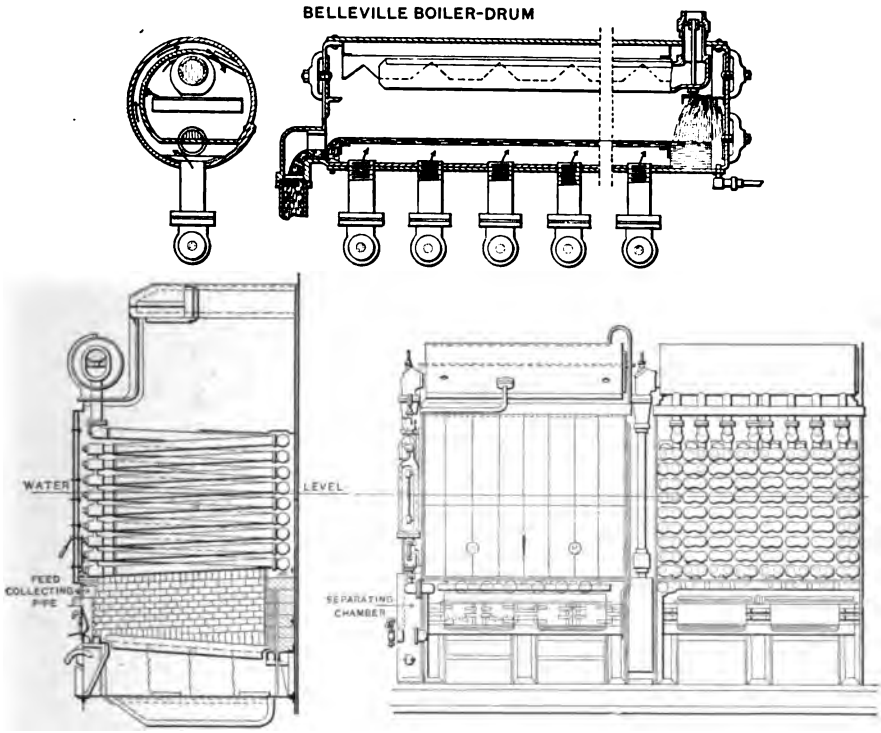
mitted both above and below the fire to become thoroughly mixed. In the shorter Admiralty boiler this has not been allowed for. The same fault is very apparent in the combustion chamber. The width in usual practice is 2 feet 9 inches or 3 feet, while in the Admiralty design the mean width is 2 feet 3 inches. Thus the space allowed for the mixing of the gases is much under that allowed in usual practice. A 3 inches. Instead of lengthening the tubes to allow for forced draught, they have been shortened.

One of the greatest troubles encountered by Navy engineers is priming, and one of the most prolific sources of priming is small steam space above the water. In the usual practice 0.47 cubic foot of space is allowed above the water for the steam for every H. P., yet in the new design only 0.32 cubic foot of space has



A BELLEVILLE BOILER. MADE BY MESSRS. MAUDSLAY, SONS & FIELD, LTD., LONDON

number of valuable experiments were made by Sir John A. Durston to determine the temperature of the gases at each point of a tube fitted in a cylindrical boiler. The temperature of these gases was 1550° at the combustion chamber end and 887° at the smoke-box end. The length of the tube was 6 feet 8 inches, and this was a high temperature for the gases to escape at after passing through a clean tube. Yet the length of the tubes in the new Admiralty boiler with forced draught is only 6 feet been allowed. It will be observed that the water space between the back of the boiler and the combustion chamber has parallel sides. The width of this space is 7½ inches. It has often been held that the sides should be a little inclined so that they may the more freely give off steam, but there are practical drawbacks to such an arrangement. The screwed stays in such a case are of unequal lengths, and the taper compels the use of beveled washers below the stay nuts; this causes more risks to be

H. M. S. "MINERVA." EQUIPPED WITH CYLINDRICAL RETURN-TUBE BOILERS

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taken in making the joints steam-tight. Next will be observed the much smaller ratio of heating surface to grate area in the Admiralty boiler than in the other. In the first the ratio of heating surface to grate area is 33.5, as compared with 45 in the other case. The effect of this is to allow a much greater percentage of the total heat to pass into the uptake not utilised.

It will thus be seen that the effect of a smaller furnace, smaller combustion chamber, and shorter tubes is to reduce the economy of fuel and boiler efficiency, while the action of the flames, reflected from the bridge, is to tend to cause leakage at the tube ends.

Four types of water-tube boilers are to be fitted into the six cruisers. Two ships will be fitted with Yarrow boilers, two with Niclausse, one with Dürr, and the sixth with Babcock & Wilcox boilers. The original designs provided for the whole 22,000 horse-power to be supplied from water-tube boilers. The Yarrow boilers were to be constructed in units of 1000 H. P. each, that is, twenty-two boilers were to be the installation for the 22,000 H. P. For an equivalent Dürr installation there were to be fitted twenty-five boilers of that type, thirty-four Niclausse, and twenty-five Babcock & Wilcox. The amount of heating surface allowed by each maker per I. H. P. varied. Yarrow came first with 3 square feet of heating surface, while the others allowed 2.6 square feet. In the grate surface allowed per unit they also differed. Yarrow allowed least, namely, 1 square foot of grate surface for 20 I. H. P. developed; Niclausse and Babcock & Wilcox came about the same, namely, 12.2 H. P. per square foot of grate for Niclausse, and 12.5 H. P. in the Babcock & Wilcox type. The Dürr allowance was 14.4 I. H. P. per square foot of grate. The weights of the boilers were not given separately, but only the total weights of the machinery. In these weights there was not a great difference, and it would be inappreciable compared with the differences in the coal consumption on a long voyage. The following table gives the principal figures regarding the different types:—

	Belleville	Yarrow	Dürr	Niclausse	Babcock & Wilcox
No. of boilers	31	22	25	34	25
Heating surface sq. ft.	50,300	66,000	57,000	57,200	59,000
Grate area, sq. ft.	1,610	1,100	1,525	1,800	1,750
H. S. sq. ft. per I. H. P.	2.29	3	2.50	2.6	2.68
Total wt. machinery, tons	1,750	1,832	1,852	1,892	1,857
I. H. P. per ton	12.57	12	11.57	11.62	11.87

The original intention was to fit the new cruisers throughout with water-tube boilers. But finally it was decided to fit them with mixed types, one-fifth power cylindrical and four-fifths water-tube. This involved designing the engines to be suitable to work at 210 pounds steam pressure, which was that for which the cylindrical boilers were to be designed. In the original design the Yarrow boilers were to be constructed to generate steam at 250 pounds pressure, while the Babcock & Wilcox were to carry 260 pounds pressure. In the new arrangement steam from each type is to be the same,—210 pounds.

The change which the lower pressure of steam involves in the design of the engines will be illustrated by the difference in the machinery of the two King Edward VII. battleships. The *Duncan* and one of the King Edward VII. battleships are fitted with water-tube boilers supplying steam at the higher pressures. The maximum indicated horse-power developed by the engines is 18,000, while the cylinder dimensions are 33½ inches high-pressure; 54½ inches intermediate; and the two low-pressure cylinders are each 63 inches in diameter; the common stroke is 48 inches. In the second King Edward VII. class battleship, with mixed boilers and a steam pressure of 210 pounds, the cylinder dimensions are 38 inches high-pressure; 60 inches intermediate; and the two low-pressure each 67 inches in diameter. The stroke is the same as before,—48 inches. The piston speed is also the same,—960 feet per minute,—and the

H. M. S. "HERMES." BABCOCK & WILCOX BOILERS. 10,000 H. P.

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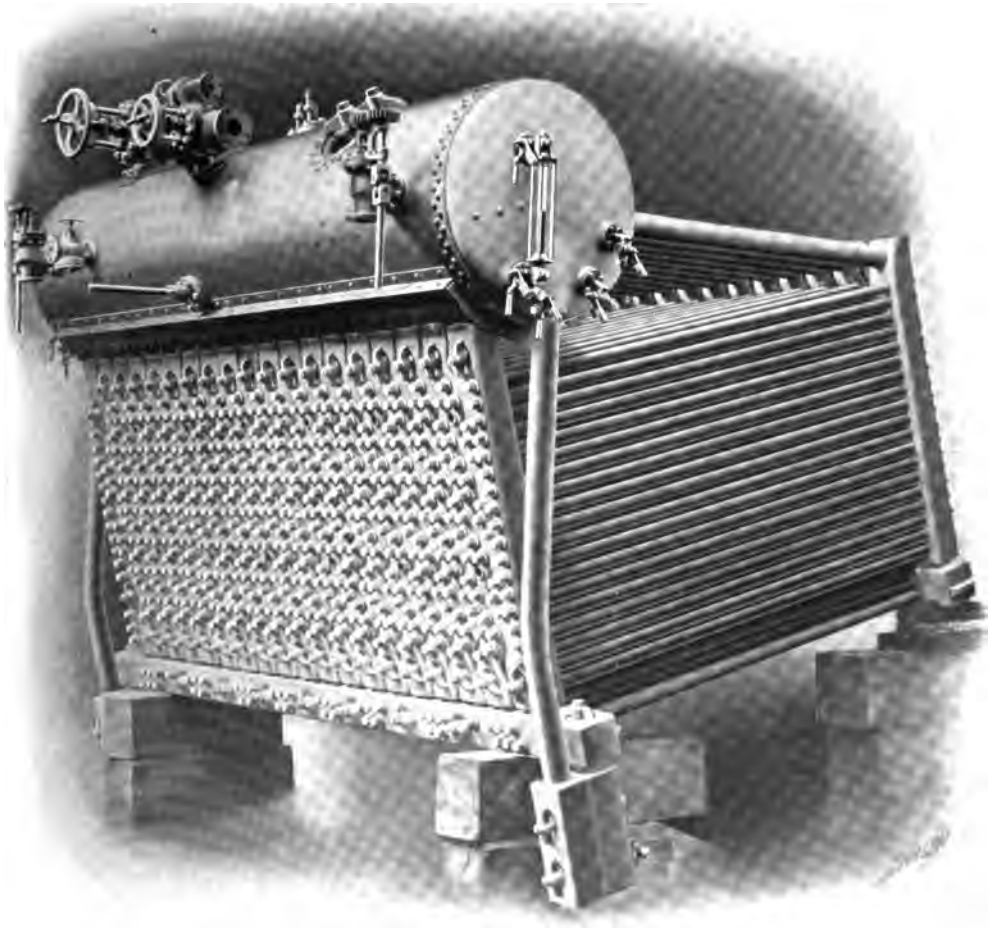
revolutions, 120 per minute. The battleships are 425 feet in length, 78 feet beam, and 43 feet depth, with a mean draught of 26 feet 9 inches. The maximum speed is 18½ knots.

The reason for coming down to low pressures again is not given, but it had probably something to do with the exhaustive trials and the observations made with the cruisers *Hyacinth* and *Minerva*. The result of these trials showed no advantage in favour of the high-speed, high-pressure engines. In fact, under certain conditions the high-pressure engines showed less efficiency. The results of these as obtained by the Boiler Committee supply some important data in the question of high pressures. In the case of the *Hyacinth*, having water-tube boilers, high pressures, and high speed of engines, the revolutions per minute are 23 per cent. higher than the revolutions of the engines of the *Minerva*, and the mean pressure of steam in the engines is in the same proportion. The *Saxonia*, of the Cunard Company, was also under trial, in order that comparisons might be made between the performance of a mail liner and the ships of the Navy. These trials clearly



H. M. S. "SHELDRAKE" BABCOCK & WILCOX BOILER, PRESSURE PARTS, CASING REMOVED

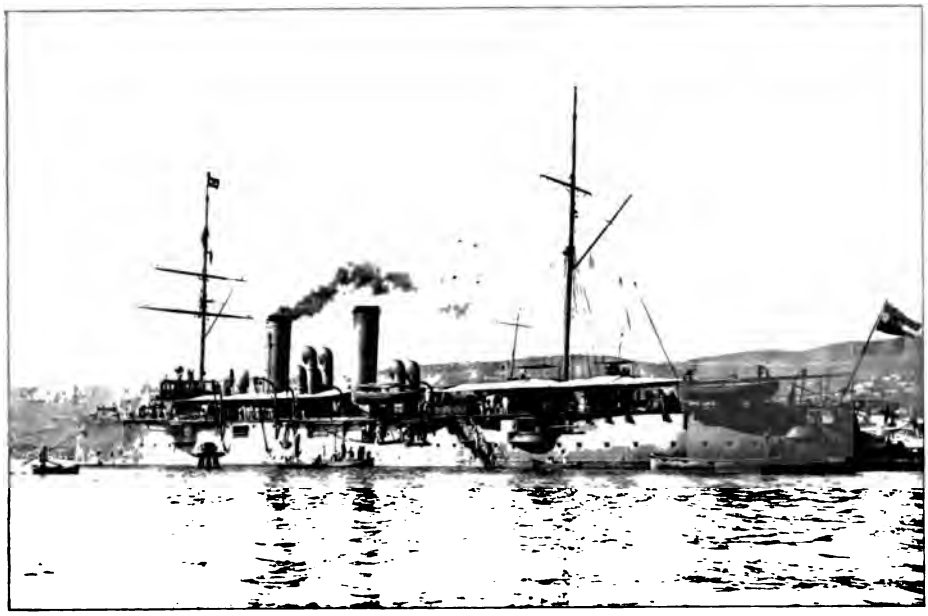
THE "FRIESLAND" OF THE DUTCH NAVY, EQUIPPED WITH YARROW BOILERS AND CYLINDRICAL BOILERS

proved that the engines of the cruiser *Minerva* were quite as high in efficiency as those of the *Saxonia*, although the piston speed was very different. The piston speed of the *Hyacinth* and *Minerva* engines was 855 feet per minute, while that of the engines of the *Saxonia* was only 702 feet per minute. The mean pressure of the steam on the pistons of the *Minerva* and *Saxonia* was 39 pounds. The *Minerva* engines worked better at powers below 7200 I. H. P. than did the *Hyacinth*, but above that power the *Hyacinth* engines showed higher economy. At 2000 and 5000 I. H. P., for example, the steam consumed per I. H. P. by the *Minerva* and *Hyacinth* engines is given in the following table:—

	Minerva	Hyacinth	
Steam per I. H. P.	18.2	18.8	at 2,000 I. H. P.
" "	15.15	16.68	at 5,000 "
" "	18.86	16.88	at 8,000 "

With steam jackets the *Hyacinth* used more steam at 5000 I. H. P. than shown above, the consumption running up to 17 pounds per I. H. P. The best results obtained from the *Minerva* engines was a consumption of 13.82 pounds of steam per I. H. P. The consumption of the quadruple expansion engines of the *Saxonia* was 13.47 pounds per I. H. P. The efficiency ratio, that is, the ratio of the efficiency obtained to that possible in the engines, was highest in the older *Minerva* engines. In these it was 65, in the *Saxonia*, 62.8, and in the *Hyacinth*, 54. The *Hyacinth* engines had a slight advantage in space occupied, this space amounting to 28,200 cubic feet; the *Minerva* engines occupied 29,240 cubic feet. The space occupied per maximum horse-power developed was 2.8 cubic feet in the case of the *Hyacinth* and 3.4 cubic feet for the *Minerva*, that is, where 10,180 I. H. P. were developed by the engines of the *Hyacinth*, and 8651 by those of the *Minerva*. But this comparison is hardly fair to the *Minerva*, since her engines were capable of developing 9800 I. H. P. The total weights of the engines, shafting, propellers, spare gear, and evaporating plant was 378.4 tons for the *Hyacinth* and 364.8 tons for the *Minerva*, so that, on the whole, the long-stroke engines of the *Minerva* are the lighter.

It is interesting to compare the mer-



THE AUSTRIAN CRUISER "ASPERN," COMPLETELY EQUIPPED WITH YARROW BOILERS, 7800 H. P.

cantile marine design with that of the Navy. In the power expected to be developed there is not much to choose between the *Minerva* and the *Saxonia*. The engines of the latter are designed to work most economically when developing 9000 I. H. P. They are quadruple expansion, and use only 13.47 pounds of steam per I. H. P. per hour during the ordinary voyage. At 8000 I. H. P. the *Hyacinth* used 16.88 and the *Minerva* 18.86 pounds of steam per I. H. P.

But although cargo, earning money, is carried by the *Saxonia* there is no severe restriction as to space and weight for machinery as there is in the case of the naval ships. The engines of the *Saxonia* have cylinder diameters of 29, 41½, 59, and 84 inches, with a common stroke of 54 inches, while their weight amounts to 709 tons. The boilers alone come to 910 tons of weight, but then the consumption of coal is only 1.29 pounds per I. H. P. per hour, as against about 2 pounds in the cruisers when doing their best. If, then, about ¾ pound of coal per I. H. P. is being consumed extra per hour as a consequence of the lighter engines, it means that the advantage will be lost in the extra weight of coal carried. For 9000 I. H. P. the extra coal burned would be three tons per hour, and the saving of weight would be lost in 110 hours, that is, in 4½ days. Under these conditions the saving of weight would be lost in extra coal necessary long before the Atlantic was crossed.

The question of the boilers to be fitted may be now considered. The first point evident is that the British Admiralty has not yet made up its mind as to the question of tubes,—whether they should be inclined at a small angle to the vertical or at a small angle to the horizontal. Both types are to be fitted in the new cruisers. The Yarrow is of the former type; the three others are of the latter.

The Yarrow type has been modified considerably, as compared with the original design fitted into torpedo craft. In the earlier boilers the tubes were about ⅞-inch diameter and were very thin. Boilers with these small tubes had great power and yet occupied comparatively little space, and their weight was small. The unit of power for torpedo-boat destroyers appears to be 1500 H. P. The

four Yarrow boilers shown on page 410 are capable of developing 6000 H. P. Their weight, with water, amounts to about twelve tons per 1000 horse-power. Another boiler of this type, of which the writer has figures, is the one made by Messrs. J. S. White & Co., of Cowes, shown on page 412. The following are the parts:—

Heating surface in each	2,300 sq. ft.
Grate surface	88.5 sq. ft.
I. H. P. at 2¼ sq. ft. of H. S. per I. H. P.	1,083
Actual evaporation on trial equals 22,214 lbs. from water at 50° to steam at 180 lbs.	

Weights	Tons	Cwts.	Qrs.
Each bare boiler	8.	12.	2
Casings, fire bars, lagging zinc	3.	0.	3
Mountings	--	7.	3
Water to working level	2.	14.	0
Total	15.	4.	0

The length over casings	10 ft. 2 in.
Height from ashpan to top of drum	8 ft. 7 in.
Width over all	9 ft. 4¾ in.

The accessories in the stokehold are, one fan and engine in the engine room, one main feed pump, one auxiliary feed pump, and one feed regulator. For the purpose of placing on record what can be done with respect to the supply of steam for a given horse-power the writer asked Messrs. White to supply him with particulars regarding weights and space occupied by this type of boiler for 7000 H. P., and the following were given:—

The number of boilers proposed to supply the quantity of steam necessary for 7000 I. H. P. was four, each with 3750 square feet of heating surface and 61.62 square feet of grate surface, each fitted with a central division in the grate and grate regulator. The working pressure was to be 250 pounds. The dimensions are given in the following table:—

	Ft.	In.
Length over the casings	9	3
Length from front of casing to extreme back of downcaste	10	11
Length from front of casing to bulkhead at back	11	3
Width over all	13	5
Height from bottom of ashpan to top of drum	11	3

Grate, two divisions each 7 ft. 3 in x 4 ft. 3 in.	
Two rows of tubes next fire 1¾ in. diam.	to S. W. G.
The remaining rows 1 in. diameter	12 S. W. G.
All tubes are curved to 7 ft. 3 in. radius	
Two downcurves at back 9 in. inside diam. 5-16 in. thick	

Weights	Tons	Cwts.	Qrs.
Four boilers bare	52.	4.	0
Four sheet casings, lagging, fire-bars, bricks, etc.	17.	11.	1
Four sets of mountings with zinc slabs	1.	17.	1
Water to working level in four boilers	15.	10.	0
Total weights	87.	2.	2

The total length taken up by the boilers shown on page 412 is 68 feet, and as given above the extreme width is 13 feet 5 inches. These dimensions are given to show what can be done for the provision of steam power at small weights and space.

Now taking up again the Yarrow modification of the small-tube type, it has been already said that Messrs. Yarrow have increased the diameter of the tubes in order to increase the thickness of the metal, and, at the same time, the durability of the boilers. The enlargement of the tubes also allows of access to the interior of the tube for examination and cleaning purposes. The firm thinks nothing larger is necessary, and that, if unnecessary, it is unwise. They also claim that the principle of adhering to a given size of tube allows everything to be interchangeable in the same navy. The firm has fixed on 3 square feet of heating surface as the unit for one indicated horse-power. It will be seen by a reference to the other allowances that this is the most liberal. It allows sufficient steam to be supplied by the boilers when working under a pressure of 1 inch draught.

The total weight of the twenty-two Yarrow boilers complete, with fittings and water, comes out at 630 tons. The water alone weighs 85 tons. These weights are for the large-tube cruiser boilers. The same power could be supplied by boilers with tubes of small diameter of the torpedo-boat type, and these would weigh about one-third the weight of the cruiser boilers. Part of the difference is due to reduced heating surface per H. P. adopted in the torpedo-boat type, and much more forcing is necessary; but the main cause of the greater weight in the cruiser type is due to increased thickness of material throughout.

The circulation of boilers with tubes nearly vertical increases in proportion to the rate of working; with tubes nearly horizontal it is doubtful if this rule would hold good. Anyway, the nearly vertical tube boiler permits of forcing, so that should any of the installation be thrown out of action the remaining boilers can

be forced easily to 50 per cent. increased generation of steam beyond that for which they were originally designed.

There is no question, however, regarding the increasing favour in which this type is held by the engineers-in-chief of several of the Continental navies. Several very large ships of great steaming power have been fitted with them. The Austrian Navy has three of its cruisers, the *Zenta*, *Aspern*, and *Szigetvar*, each completely fitted up with Yarrow boilers. The horse-power of each of these cruisers is 7800. A new cruiser being built is to be of 13,000 H. P., and will be fitted entirely with them. The Dutch Navy, after careful trial over a long period, has also given them its approval. At the beginning they had three cruisers, the *Holland*, *Friesland*, and *Zealand*, fitted partly with Yarrow and partly with cylindrical boilers, the proportion being 7500 H. P. Yarrow and 2500 H. P. cylindrical. All the later-built boats are fitted with Yarrow boilers entirely.

The nearly vertical tube boilers appear to be gaining in favour. In the German Navy the Schulz-Thornycroft of the *Daring* type are being fitted in the high-speed ships entirely or in conjunction with cylindrical boilers. Battleships are mainly fitted half Schulz-Thornycroft and half cylindrical. They have tried others in the cruisers, but all are disappearing, with the exception of the Schulz-Thornycroft and the Dürr. In the United States Navy the Thornycroft-Schulz *Daring* type is in favour.

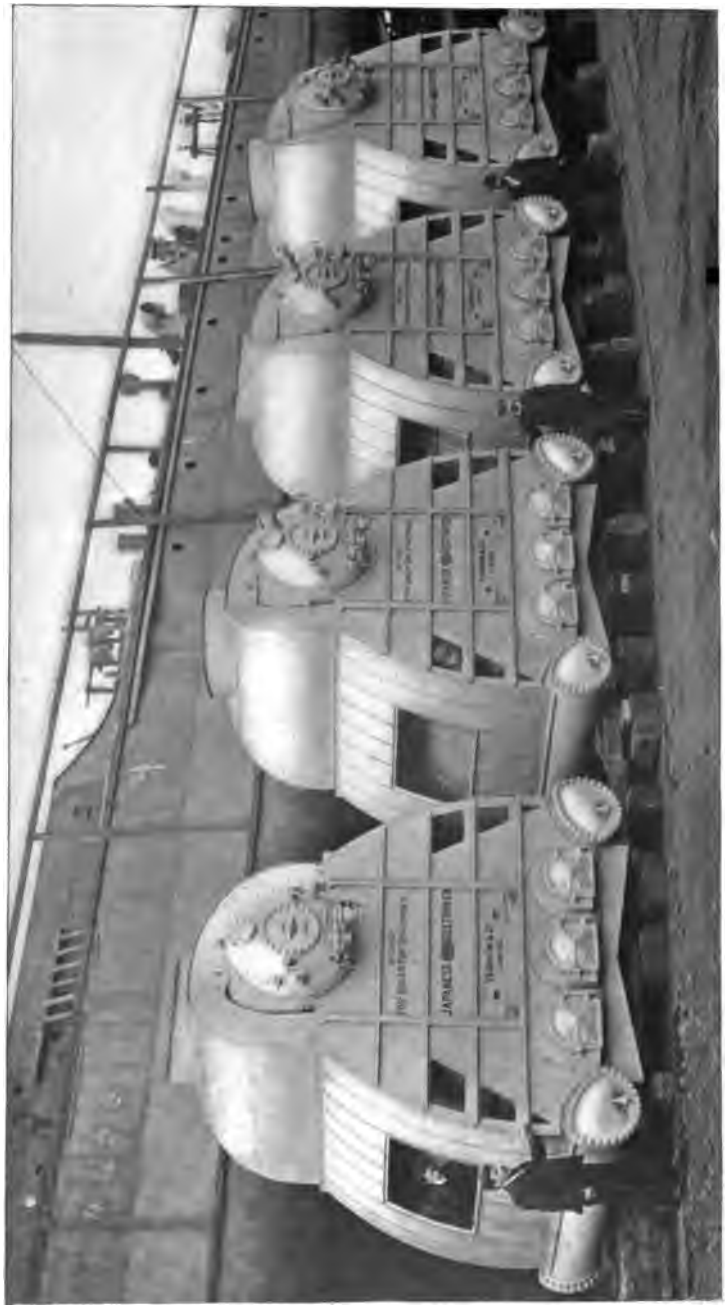
The Niclausse boiler is of French design, and for land service is constructed in Great Britain by Messrs. Willans & Robinson, of Rugby. For the Navy it is made by Messrs. Humphreys, Tennant & Co., Deptford Pier, London.

The Babcock & Wilcox boilers, made by Messrs. Babcock & Wilcox, Ltd., Renfrew, Scotland, is very well known in Great Britain, and has been fitted into many power stations. The tubes of these boilers are ordinarily about 4 inches in diameter, but those in the Navy type of boiler are made about 1⅞ inches in diameter and are much shorter. They are inclined about 15° from the horizontal, and are divided into sections, the tubes of each section being expanded at the ends into sinuous headers and staggered so as to break up the gases in their motion upwards to the uptake. The bottom row of tubes is of larger diameter than the others, and there is a blank space between the first row and the second which serves the purpose of a combustion chamber. Across the bottom of the front headers is fixed a steel box of square section which serves as sediment collector. The headers are connected to this with short tubes.

The steam and water drum is parallel to the front and is close down to the front headers, being attached to them by means of riveted joints. Baffle plates are placed at suitable places amongst the tubes so that the gases may be guided amongst them and the heat distributed as equally as possible. When the fires heat the bottom of the tubes, steam is formed and the water and steam flow together towards the back header and rise in that. Then they flow along the connecting pipes to the steam and water drum where the steam separates out into the steam space and the water flows down the front headers back to the tubes.

The boiler has been successfully fitted into some of the ships of the United States Navy, into the corvette *Ellida*, of the Norwegian Navy, and the *Zenda Arlanza*, of the Spanish Navy. The first vessel to be fitted with them in the British Navy was the torpedo gunboat *Sheldrake*. See page 405. Since then they were put into the sloop *Espiegle*. Both vessels have undergone their trials satisfactorily and are in commission. The following vessels are being fitted with boilers of the same type:—The sloop *Odin*, the second-class cruisers *Challenger* and *Hermes*, the battleship *Queen*, and the first-class cruiser *Cornwall*, and now one of the Devonshire cruisers is to be fitted with them.

Of all water-tube boilers this type has been most extensively fitted into ships of the mercantile marine. Nine of the ships of the Wilson Line have them, four of Peterson, Tate & Co., of Newcastle, and twenty of other lines. These



FOUR YARROW WATER-TUBE BOILERS, REPRESENTING 6000 H. P. BUILT FOR THE JAPANESE NAVY BY MESSRS. YARROW & CO., LTD., LONDON

range from 500 I. H. P. to 2500, and are all of them ocean steamers. On the American Great Lakes Babcock & Wilcox boilers are on a large number of steamers.

Much has been said of the difficulty of getting ships fitted with water-tube boilers to go long voyages. During the Spanish-American war orders were sent for the United States gunboat *Marietta* to proceed from San Francisco to Cuba. She is 174 feet long, 34 feet beam, 12 feet draught, and 1000 tons displacement. Her engines are twin-screw, triple expansion, with cylinders 12, 18 and 28 inches in diameter, and 18 inches stroke. She has two Babcock & Wilcox boilers, with 3620 square feet of heating surface, and a total grate area of 95 square feet. The lower tubes are 4 inches in diameter, and the upper, 2 inches. She made a speed of 13 knots during the voyage of 11,000 miles, and this was a knot over contract speed. On trials made before this voyage at speeds of 10½, 9½, and 8½ knots an hour the consumption of coal was 1.52 pounds per I. H. P. per hour. At 204 miles per day, she could make 7500 miles on her coal supply. The *Sheldrake* is fitted with four boilers with a heating surface of 9424 square feet and a grate area of 252 square feet. On trial the engines indicated 4050 H. P., burning 25 pounds of coal per square foot of grate, and made 20.6 knots on a consumption of 1.57 pounds per I. H. P. per hour. When developing 2642 I. H. P. the speed was 17.9 knots, the coal consumption 15 pounds per square foot of grate and 1.42 pounds per I. H. P. per hour. One of the merchant vessels fitted with Babcock & Wilcox boilers is the *Martello*, of the Wilson Line. She is 370 feet long, 43.6 feet in breadth, and 28.4 feet deep. The engines are triple expansion, $\frac{25\frac{1}{2} \times 50 \times 82}{57}$, and there are four boilers with a heating surface of 10,740 square feet, grate area 220 square feet, and working pressure of 220 pounds. The mean I. H. P. on trial

THE CRUISER "HOLLAND" OF THE DUTCH NAVY, EQUIPPED PARTLY WITH CYLINDRICAL AND PARTLY WITH YARROW BOILERS

WATER-TUBE MARINE BOILERS MADE BY MESSRS. J. S. WHITE & CO., COWES

THE GERMAN CRUISER "VICTORIA LOUISE," EQUIPPED WITH DUERR BOILERS

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was 2750, and the speed, 14 knots. The ship has been run over 42,000 miles.

The Niclausse boiler, made by MM. J. & A. Niclausse, of Paris, belongs to the large-tube class. It is of the double-tube variety, the tubes having an inclination of about 15 degrees to the horizon. The front water header is divided by a diaphragm into which the inner tubes are fitted. The water descends from the steam and water drum in the outer part of the front header, flows down through the inner tube to the back, and then flows along the angular space between the two and up the back space of the header again into the steam and water drum. The Dürr boiler, a German design, is of substantially similar design.

A great number of these boilers have been fitted up for land service and also into ships of the German Navy, so that considerable experience in their operation has been gained. Virtually the boiler may be said to be made up of Field tubes. Formerly these tubes were fitted into vertical or horizontal boilers to increase the circulation of the water and thus the evaporation. In the earliest boilers of this type the sides of the header were parallel, but it was found that the steam did not rise freely in them. Now the back plate is fitted in some cases at right angles to the inner tubes. As in the Babcock & Wilcox and Belleville boilers, the lower rows of tubes are made larger than the upper rows, so that there may be less risk of the steam collecting in the middle of the tube and blowing the water out in front of it towards both ends of the tubes at once.

In some cases, too, as in the Babcock & Wilcox boiler, a space is left between two of the lower rows which serves as a kind of combustion chamber. Baffle plates are introduced so as to cause the hot gases to circulate amongst the tubes and to prevent them from taking the shortest way through them to the uptake. These baffle plates are made of ⅛-inch iron plate. The diaphragm of the header is carried up to within two inches of the lowest water level in the steam and water drum, and this increases the rate of circulation, since it raises the head and pressure above the down corner side of the header.

In order that the steam may be thoroughly dried, a superheater is fitted in the uptake. This is of precisely the

THE RUSSIAN CRUISER "VARIAG," EQUIPPED WITH NICLAUSSE BOILERS

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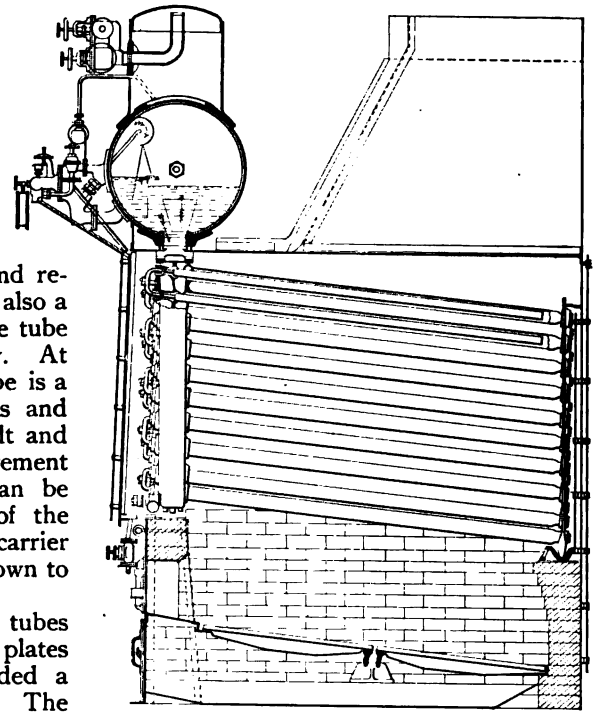
same design and construction as the Field tubes of the boiler. Two casings are fitted to the upper side of the steam drum, an inner and an outer one. To the plate of the outer casing the ends of the inner tubes are fitted, and thus they receive the steam from the inner casing which is near to the steam drum. The outer casing communicates with the outer tubes at one end and with the steam pipe at the other, and the steam flows through it from the tubes to the steam pipe. In the boilers with the walls of the header at right angles to the tubes, the tube ends are expanded into their respective plates,—the large tubes into the back plate, and the inner tubes into the diaphragm. In front of each pair of tubes in the front plates of the header is a hand-hole door for providing access to the tubes for examination and repair. In the diaphragm is also a screw plug, so that the large tube may be withdrawn if necessary. At the back end of the large tube is a conical plug, drawn outwards and made tight by a screw tail bolt and bridge-plate. By this arrangement the back end of the tubes can be examined. The back end of the inner tube is supported by a carrier which keeps it from bending down to one side.

In those designs where the tubes are not at right angles to the plates into which they are expanded a special arrangement is made. The end of the tube is made thicker by a piece being welded on. It is also made conical to fit into the conical surface made in the plate, and then it is expanded in the plate. The back and front plates are stayed by screwed and riveted bolts with holes bored through their centre. There is a nut on the inside of the inner plate and another on the outside of the diaphragm plate. The bolt is riveted over on the outside at both ends.

Boilers of this kind have been fitted into the *Baden*, *Bayern*, and *Sachsen*, the *Victoria Louise* and *Vinetie*, and into the *Prinz Heinrich* and *Grosser Kreuzer B*. In the *Prinz Heinrich* each of the Dürr boilers has a grate area of 72.6 square feet and a heating surface of 3055 square feet. The outer diameter of the large tubes is 3¼ inches and their length 6.7 feet. The ratio of heating surface to grate area is 42, and the superheating surface amounts to 169 square feet. The diameter of the steam drum is 3.61 feet and the steam space 3.2 cubic feet. On the trial trip the



ELEVATION AND SECTION OF A NICLAUSSE BOILER

average coal burned was 34 pounds per square foot of grate and per I. H. P. 2.2 pounds. The I. H. P. per square foot of heating surface was 0.364. The evaporation on trial with this boiler was 9⅓ pounds of steam per pound of coal when 17½ pounds of coal were burned per square foot of grate, and 7¼ pounds of steam when the rate of combustion was 37 pounds of coal per square foot of grate.

The Dürr boiler differs from the Niclausse mainly in constructional de-

tails. In the Niclausse boiler the aim in the design has been to make each tube a single element which can be entirely removed. The header is somewhat of the shape of the Babcock & Wilcox, being for two rows of tubes staggered. At the top this header is joined to the drum by a flange. The two tubes are jointed into the header by an arrangement called a lantern.

The inner tube, as will be seen from the illustration on page 415, receives the descending water from the outer water space of the header and this water flows back to the end of the tube, as shown, and then back along the concentric space between the two tubes to the lantern in the outer tube, rising in the back space of the header. There is a plain plate at the back, with suitable holes for taking the weights of the back ends of the tubes. The rear ends of the outer tubes are closed by screwed caps, which can be removed for cleaning and examination of the tubes. Clamps are provided at the front which are screwed against a recess in the plug of the inner tube, and these keep the joints quite firm. The lengths of the tubes are in extreme cases 7 feet.

The boiler has been fitted into a great number of ships of the French Navy, and also into the fastest cruiser of the Russian Navy, the *Variag*, built to make 25 knots, by the Cramps, of Philadelphia. They are also fitted into the *Medusa*. The trials have been very satisfactory. In a trial with one made by Messrs. Humphreys, Tennant & Co. the grate area was 19.2 square feet. With a coal consumption of 12.94 pounds per square foot of grate the evaporation from and at 212° was 11.2 pounds of water per pound of coal, while at 35 pounds of coal per square foot of grate the evaporation was 9.59 pounds of water per pound of coal. Priming amounted to only one per cent.

On the French cruiser *Friant* the twenty boilers of the Niclausse type, including casings, firebrick linings, etc., not counting 200 tons with uptakes and water, weighed only 255.9 tons. The length of each tube is 7 feet 4½ inches; the length of grate, 6 feet 6½ inches; and the outside diameter of the tubes, 3¼ inches. The total grate area of the twenty boilers is 775 square feet, and the total heating surface, 23,200 square feet. On the maximum power test 9438 I. H. P. were developed, and the consumption of coal was 29.94 pounds per square foot of grate per hour. On the 24-hour trial at normal power 7826 H. P. were developed for 6 hours, while 8547 were developed for 3 hours of the total 24 hours. The mean I. H. P. was 6279, and the hourly coal consumption, 1.84 pounds per I. H. P.

Mr. Charles H. Cramp, in writing of the performance by the *Variag*, said that the extraordinary performance of the ship was due to the fact that the Russians, while making exceptional requirements, were willing to pay the price for them.

Since writing the above regarding the Devonshire cruisers the new designs for the new type by the naval constructor, Mr. Philip Watts, have been published. They are on lines which may be described as a heavy Elswick type, like the *O' Higgins* or the *Hai-Chu*. These latter cruisers for the British Navy, however, carry heavier guns and thicker armour than any of the light, high-speed cruisers built by the Armstrong firm for China, Chili, or the Argentine Republic. With the usual splinter deck they will carry a 6-inch belt, and the guns will be protected. The armament also will be heavier than that of any of the British cruisers. It was formerly the custom to fit only 6-inch guns as the heaviest pieces carried. and the cruisers of the *Diadem* class carried eleven of them. At the bow and the stern of the *Sutlej* class there is fitted a 9.2-inch gun. But the *County* class had only 6-inch guns and a 4-inch belt, and thus were far outclassed by the small cruisers of the Argentine Republic as far as gun power was concerned, for the Elswick cruisers always carried 8-inch guns as their heaviest pieces even with so small a displacement.

As these 8-inch guns throw a 250-pound shell and could go through the sides of any battleship in the British Navy at a range of two miles, the only apparent advantage in carrying a

9.2-inch gun lies in the perforation being one inch bigger in diameter. This, after all, is a doubtful advantage, since twelve shots a minute by 8-inch guns could be made against four shots with the same weight of 9.2-inch guns. Besides, the armour of the new cruisers will be no protection whatever against the guns of an opposing cruiser of any of the great navies.

In the matter of speed, the new cruisers just designed will, on paper, be better than the *County* class. They are to be supplied with sufficient engine power, —24,000 H. P.,—to give them a steady speed of 22 knots an hour, and are to be capable of putting on a spurt of 25 knots for three hours. It is understood, however, that they will be fitted with water-tube boilers, and no doubt these are being improved by the suggestions made by Sir John Durston to the builders. The recent return issued by the Admiralty in response to Lord Charles Beresford shows that in some cases the charges for repairs for water-tube boilers are somewhat heavy, but the heavier charges were for the worst class of Belleville boilers. In some cases, when other types of water-tube boilers were used, the expenses for repairs were not nearly so heavy; some indeed did their ordinary work without any trouble. On the whole, the new cruisers are expected to make and keep the speed set down for them; but a higher speed and quite as stable a cruiser might have been secured with less weight to carry. They are unsuited for the battle line for want of sufficient thickness of armour, and they might have been more suitable for something else. They could not capture a *Deutschland*, and, therefore, would fail to do proper cruisers' work. The American President's message to the Congress respecting the Navy of the United States also causes us to compare the most recent British cruisers with those of other countries. President Roosevelt says:—"We have deliberately made our own certain foreign policies demanding the possession of a first-class navy. The Isthmian Canal will greatly increase the efficiency of our navy if our navy is of sufficient size; but if we have an inadequate navy, then the building of the canal will be merely giving a hostage to any power of superior strength. The Monroe doctrine can be backed up only by a thoroughly good navy."

The question then arises whether the British Navy is being outclassed in cruisers by that of the United States. This can be best understood by considering the United States cruisers *Tennessee* and *Washington* and comparing them with the *Powerful* or the *Duke of Edinburgh*. The two American cruisers are to be of 15,959 tons displacement, heavier than any of our battleships, save four, and are to carry four 10-inch guns. The belt is to be of the same thickness as that of the *Duke of Edinburgh*, but the propelling power is greater, and a speed of 22 knots is to be maintained. The weak point of the United States Navy is speed, and these new cruisers could not capture the *Deutschland;* but in all other respects they outclass any cruiser in the British Navy. Should the *Duke of Edinburgh* fail in the matter of speed, as all the other cruisers have done, then the cruisers of Great Britain are outclassed indeed, and the United States will have gained one point towards a first-class, superior navy.

FUEL BRIQUETTES IN GERMANY

HOW THEY ARE MADE AND USED

By Frank H. Mason

AMONG the several branches of German industry which deserve attention by reason of their economy, their recovery or utilisation of some raw material which exists unused, or because they involve the most intelligent application of scientific knowledge to technical processes, may be reckoned the manufacture of briquettes from brown coal, peat, and the dust and waste of coal mines. Briquettes form the principal domestic fuel of Berlin and other cities and districts in Germany; they are used for locomotive and other steam firing, and are employed for heating in various processes of manufacture. For all these uses they have three tangible advantages:—They are clean and convenient to handle; they light easily and quickly, and burn with a clear, intense flame; when made of lignite or peat they burn practically without smoke, and are, withal, the cheapest form of fuel for most purposes.

Like most other important German industries, the briquette manufacture is controlled by a syndicate which includes among its members thirty-one firms and companies, or more than nine-tenths of all the producers in Germany, and regulates the output and prices for each year. From the official report of the syndicate for 1901, which has recently appeared, it is learned that the total output during that year was 1,566,385 tons, to which is to be added the product of makers outside the syndicate, consumed at works, small retail sales, etc., making a grand total of 1,643,416 tons.

The average selling price in large quantities was 13.33 marks per ton, against 12.27 marks for the year previous, so that, notwithstanding the general relaxation of industrial activity and the diminished pressure upon the coal supply, the ruling price was the highest that had been realised since 1891. Of the 1,566,385 tons sold during 1901 by the syndicate, 749,208 tons were taken by the German railways, 124,380 tons were sold to retailers, 497,136 tons were sold to factories and works of various kinds, and 149,089 tons, or 9.8 per cent., were used by German merchant steamers and the navy, or exported to the German colonies or neighbouring European countries.

The following tabulated statement shows the production, the sales of the syndicate, and the mean price per ton for the past eleven years:—

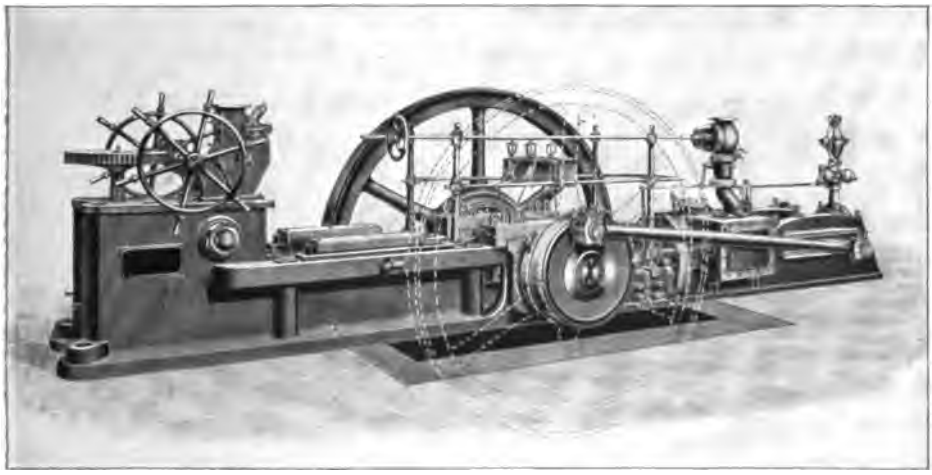
Year	Production Tons	Sales of Syndicate Tons	Price per Ton Marks*
1891	482,495	202,780	12.67
1892	533,075	516,508	10.47
1893	694,025	645,144	9.08
1894	745,414	719,258	8.82
1895	796,363	780,185	9.07
1896	830,985	818,300	9.34
1897	943,738	934,221	9.99
1898	1,078,113	1,245,269	10.22
1899	1,530,816	1,485,130	10.66
1900	1,563,928	1,519,811	12.27
1901	1,566,385	1,560,230	13.33

* A mark is about equal to an English shilling, or, in American money, 23¾ cents.

The syndicate produces to a large extent briquettes made from coal screenings which require a matrix or binder of some plastic, inflammable material, and for this purpose 116,956 tons of mineral pitch were used, which cost on an average about $10.25 (£2.1.0) per ton, delivered.

It need hardly be said that the general use of briquettes for domestic fuel in a large, densely built city, as well as for generating steam in a number of electric generating plants and factories, must have a decided and beneficial influence in reducing the smoke, which in many places has become a persistent and

IN A BRIQUETTE FACTORY, EQUIPPED BY MESSRS. ROEHRIG & KOENIG, MAGDEBURG-LUDENBURG



ONE OF THE BRIQUETTING PRESSES SHOWN IN THE PLANT ABOVE

oppressive nuisance. Berlin, although a busy manufacturing city, ranks as one of the cleanest and best kept in Europe.

One of the first things usually noticed by American and British travellers visiting the German capital for the first time is the absence of that cloud of dusty smoke that overhangs so many other towns and cities. The reason for this lies in three facts:—The preponderant use of coke and lignite briquettes, which are practically smokeless; the skillful, scientific construction of boiler furnaces and chimneys; and, finally, the high standard of skill that is taught and enforced among firemen who stoke fur-

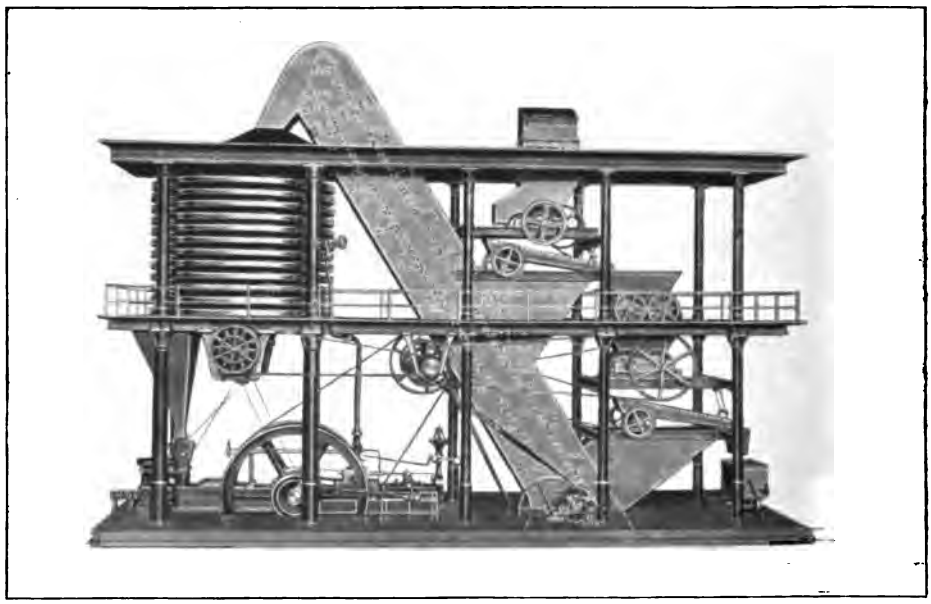
naces with coal for steam and manufacturing purposes.

It is not every strapping labourer who can shovel coal who is permitted to stoke a boiler furnace in Germany. Before he can assume such a charge he must be taught the theory and practice of economical, scientific firing. The Silesian coal used here in most large steam plants and factories is rich in bitumen and would rank below many of the bituminous coals of the United States, and yet the long, dense, trailing clouds of smoke from mill and factory chimneys which are so familiar a sight in many other cities are rarely seen in this section of Germany, where the indiscriminate shoveling of raw bituminous coal into the steam and other furnaces is considered an ignorant and wasteful proceeding.

Coke making in retort ovens, by which every element is saved and bituminous coal is converted into smokeless coke and gas, is another important factor in German fuel economy and abatement of the smoke nuisance. If other municipalities beyond the economic range of anthracite are ever emancipated from their present vassalage to the smoke incubus it will be through the enforced use of one or more of three forms of prepared fuel, viz., coke and fuel gas made in closed ovens from bituminous coal, and briquettes made from lignite, peat, and other inferior materials by processes which have been invented, tested, and proven to be efficient by the older and more economical countries of Europe.

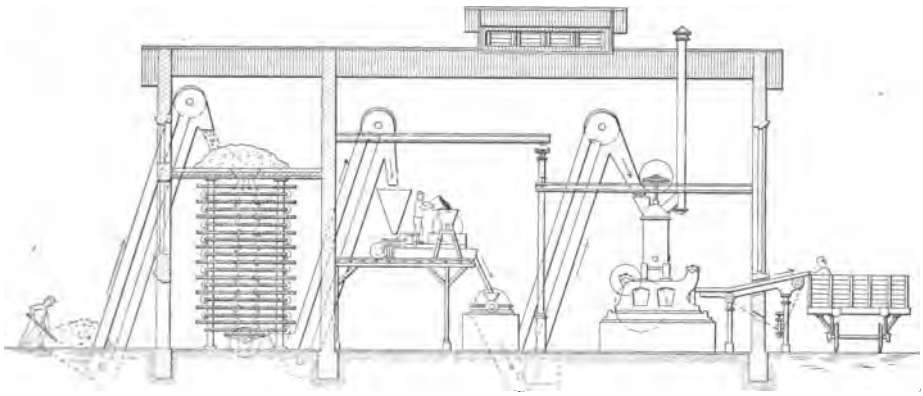
EXTENT OF THE BRIQUETTE INDUSTRY IN GERMANY

There were in operation in Germany at the close of 1900 eighty-nine manufactories of fuel briquettes, some of which,—for example, the "Hercules," the "Seven Planets," and the "Tiefbau," at Dalhausen, on the Ruhr,—produce each more than 100,000 tons annually. Briquette works are divided in respect to the material employed into two general classes, viz., those which make briquettes from brown coal (lignite) or carbonised peat, with or without the addition of a bituminous matrix or binder; and, second, those which use as a basic material coal dust or slack,—the waste of soft-coal mines.



A BRIQUETTING OUTFIT MADE BY THE ZEITZER EISENGIESSEREI UND MASCHINENBAU AKTIEN GESELLSCHAFT, ZEITZ

Of the latter class, Messrs. Franz Haniel & Co., of Ruhrort, on the Rhine, who have works at several points along the Rhine, are representatives. The great Gruhl establishment at Brühl, the preparation to produce a high-class fuel; hence the several more or less successful patented processes for carbonising peat into so-called peat coal,—an artificial product which can be used either in

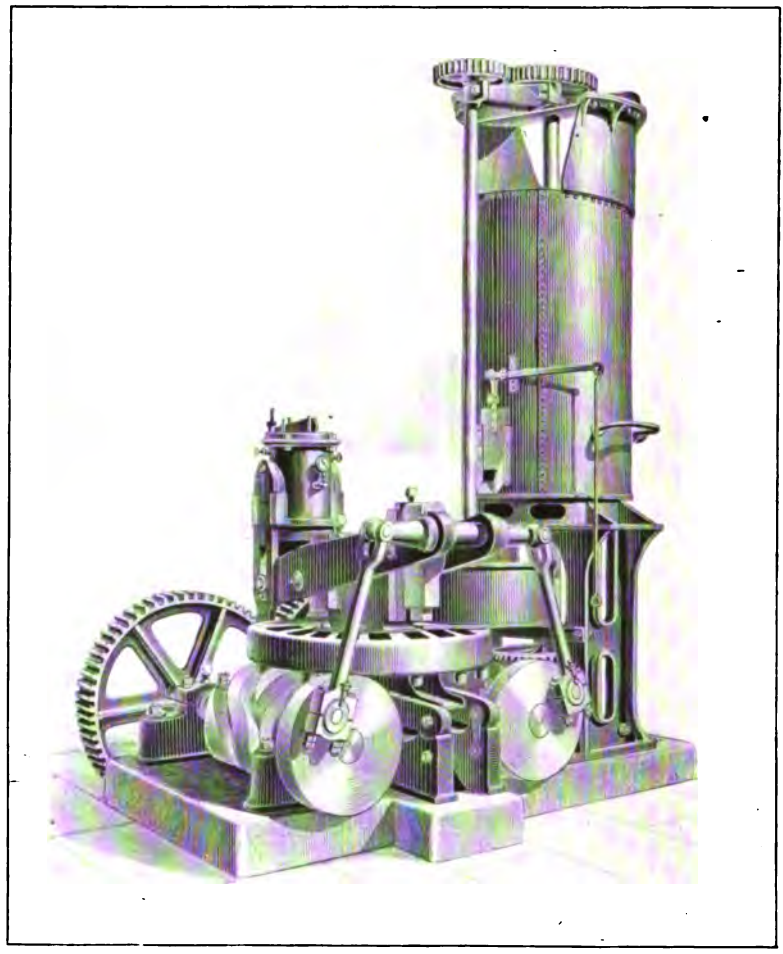


WORKING DIAGRAM OF A BRIQUETTING PLANT SUPPLIED BY THE ZEITZER EISENGIESSEREI UND MASCHINENBAU-AKTIENGESELLSCHAFT, ZEITZ. THE RAW MATERIAL ENTERS AT THE LEFT, PASSING THROUGH A STEAM DRYING APPARATUS, THEN IN SUCCESSION TO A MIXING MACHINE, DISINTEGRATOR, KNEADING MACHINE, AND PRESS, FROM WHICH LAST IT EMERGES IN BRIQUETTE FORM

"Donatus" works at Liblar, near Cologne, and the Thuringian Aktiengesellschaft, at Deuben, near Halle, are typical examples of factories which make briquettes from brown coal, which is abundant and cheap in many sections of Germany. In the last-named establishment no matrix or binder is used. The lignite is crushed, moistened with water to the consistency of mortar, then passed through a machine, which, by compression under heat, develops the bitumen in the material and renders the mass so plastic and adhesive that it moulds rapidly into smooth, glistening briquettes of a black or dark-brown colour, which are practically smokeless and leave a reddish-brown ash after combustion.

All processes of this kind are based upon the fact that lignite is a vegetable coal of more recent formation, and, therefore, less perfectly carbonised structure than anthracite or bituminous coals, has lower caloric value, and requires to be compressed and further carbonised by artificial means. Turf or peat is a still more recent formation, and requires proportionately more artificial irregular lumps or moulded into briquettes.

In all that concerns the manufacture of briquettes from brown coal, or from the slack and waste of bituminous coal mines, the processes employed in France and Germany have long passed the experimental stage and become a standard commercial industry. If others are really interested in the subject, there is no need that they should risk any large sums of money in uncertain experiments. They have only to study the machinery and methods employed in European countries, compare their crude materials with those found and used here, and they can thus start at the point of technical knowledge which Europeans have reached after many years of experience. When, about ten years ago, attention was called to the German system of making blast-furnace coke in retort ovens, which saves the valuable volatile elements of the coal, it was thought worth while by certain American iron makers to bring over two carloads of Connellsville coal to be coked as a test by the German process. The complete



ONE OF THE PRESSES USED BY MESSRS. SCHUECHTERMANN & KREMER

success of that experiment decided the introduction of the standard German (Otto-Hoffman) type of coking oven into the United States.

Something similar, it would seem, might profitably be done with the materials which British and American makers have not yet succeeded in converting into satisfactory briquettes. There are experienced engineers and a dozen manufacturers of briquette-making machinery who would gladly cooperate in these tests, and would furnish machinery adapted to working the material thus technically defined. Upon a basis of such tests plans and estimates could be obtained for the erection of plants in other places with specified daily capacity. Among the builders of briquette-making machinery in Germany the following may be cited as of standard reputation, the first two named being more specially concerned with apparatus for making briquettes from coal dust and slack, while the others build machinery for briquette making from brown coal and peat:—Messrs. J. Witt & Co., Horrem, near Cologne; Schüchtermann & Kremer, Dortmund; Tigler Maschinenbau Aktiengesellschaft, Meiderich-on-Rhine; Röhrig & König, Magdeburg-Ludenburg; Maschinenfabrik Buckau, 82 Schönebecker Strasse, Magdeburg; Zeitzer Maschinenbau Aktiengesell-

schaft, Zeitz, Saxony; E. Fietsch & Co., Thurm Strasse, Halle a. S.; and Eduard Schloemann, Düsseldorf.

MACHINERY FOR MAKING PEAT BRIQUETTES

It remains to speak of several recently invented and patented processes by which artificial coal or briquettes have been more or less successfully produced from peat by the application of machinery or methods not yet fully established on an industrial basis. Inevitably, a description of such a process must rest to a greater or less extent on the specifications and claims of its inventor, and it will be understood that in the following brief citations no opinion or estimate is offered of the practical value of the methods described.

The Stauber process for drying moist substances was first brought into prominent notice in connection with peat-coal manufacture in 1901, when the Imperial Testing Station at Charlottenburg announced, as the result of experiments tried with peat briquettes made by the Stauber system, that they contained 45.14 per cent. of fixed carbon, 4.54 per cent. of hydrogen, 29.34 per cent. oxygen, and 9.09 per cent. ash, and had a thermal value of 3806 calories. The Stauber system, as thus applied, includes a process for rapidly drying the moist peat by means of heated and compressed air within a closed chamber or channel, communicating with pipes in such manner that heated air can be forced through the drying channel and cold air through the outlet pipe, the effect being that the cold air quickly absorbs the hot, saturated air out of the drying chamber and condenses it, thus greatly stimulating the process of evaporation by which the peat is dried.

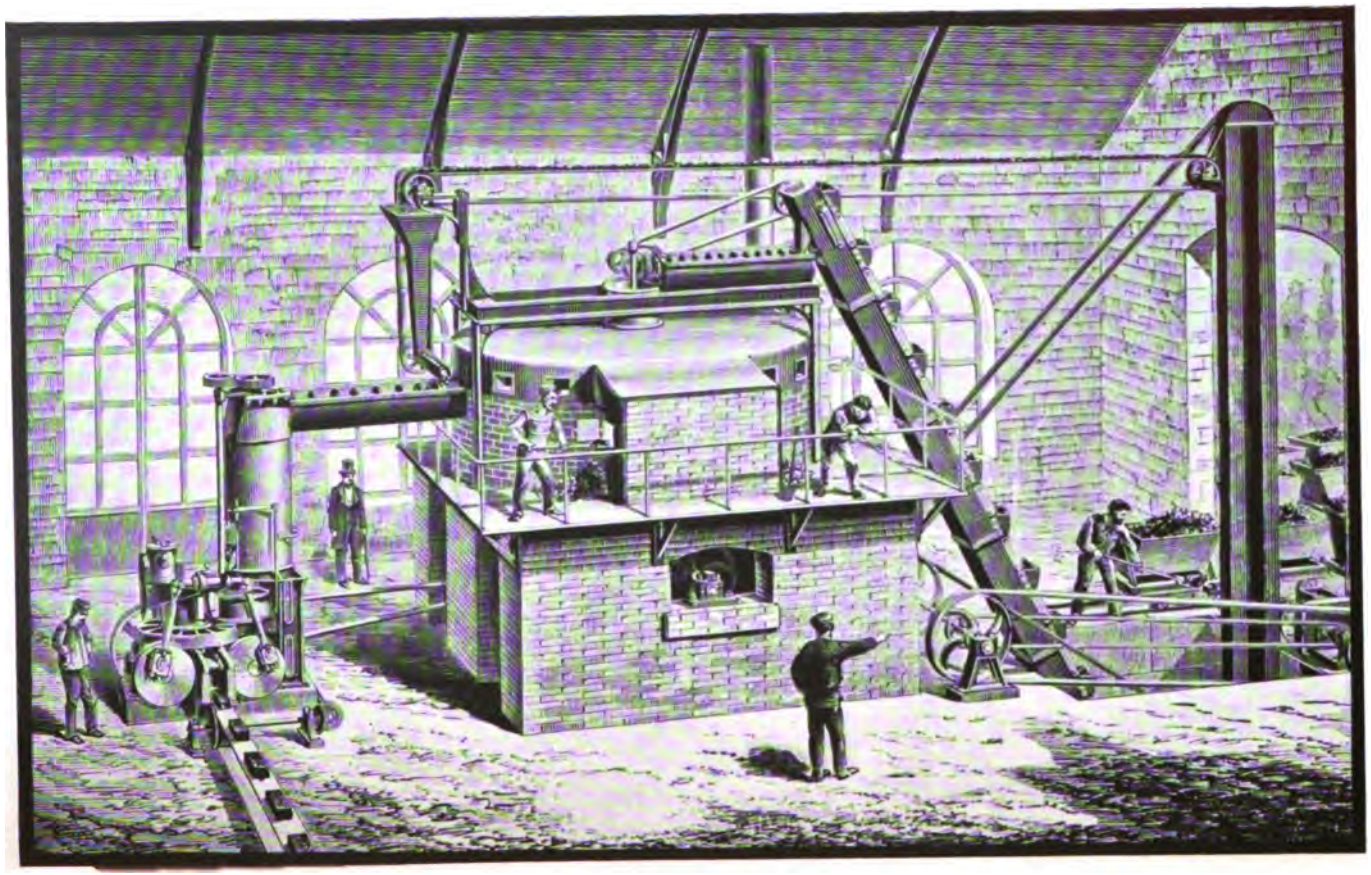
Peat in its raw state contains from 70 to 85 per cent. of water, and, in the humid climate of Northern Europe, is usually a very difficult material to dry. It is claimed for the Stauber method that it reduces the moisture to 18 or 20 per cent. quickly, effectively, and, what is important, without changing the chemical composition of the peat. The drying machine is of boiler form (cylindrical), and of a size to conveniently produce 5 tons of dried peat per day. In a large plant this unit would be simply multiplied, as a number of machines can be worked with air currents generated by the same engine. A large plant for working the process is now in course of erection near Königsberg, on the Baltic Sea, and another is already in operation at Ostrach, in Würtemberg. The peat coal can be used as locomotive or other fuel either raw, or it can be coked, and produces a coke wholly free from sulphur and as valuable as charcoal for certain industrial purposes.

Estimates furnished by the company give the cost of a plant capable of turning out fifty tons of peat briquettes per day as follows:—

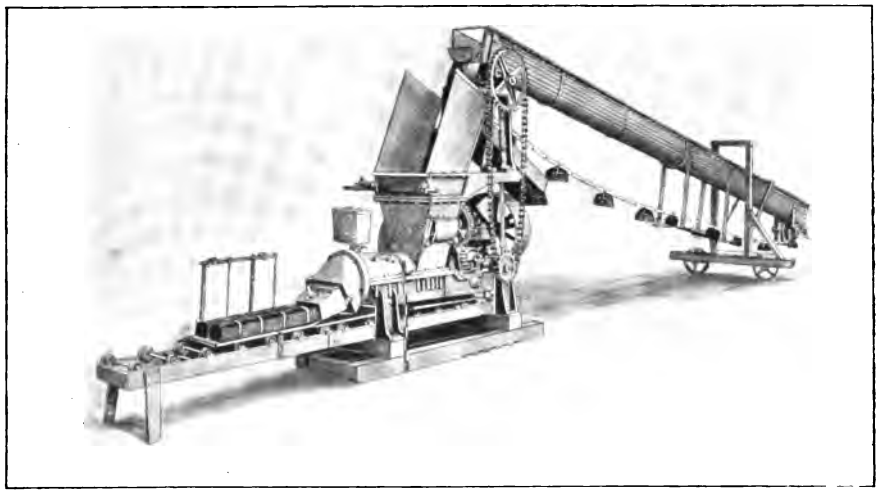
	Marks		
Buildings	60,000	=$14,280	=£2,856
Machinery	75,000	= 17,850	= 3,570
Steam engines and fixtures.	15,000	= 3,570	= 714
Means of transporting material and product	15,000	= 3,570	= 714
Total	165,000	=$39,270	=£7,854

SPECIMEN BRIQUETTES MADE BY MESSRS. SCHUECHTERMANN & KREMER. THEY RANGE IN LENGTH FROM 6 TO 12 INCHES, IN WIDTH FROM 3 TO 8 INCHES, AND IN THICKNESS FROM 2½ TO 4½ INCHES. THESE ARE CURRENTLY USED SIZES

A second process is that invented by Mr. F. Schülke, of Hamburg, the salient feature of which is that the turf or peat used is cleaned of roots, stones, etc., then liquefied by water and pumped through a pipe line several miles to the works, where, as claimed by the inventor, it is leached and converted by heat and pressure into briquettes at a



A BRIQUETTE OUTFIT SUPPLIED BY MESSRS. SCHUECHTERMANN & KREMER, DORTMUND. THE RAW MATERIAL COMES IN AT THE RIGHT, IS CARRIED TO A KNEADING MACHINE AND BRIQUETTE PRESS AT THE LEFT, FROM WHICH IT ISSUES AS FINISHED PRODUCT



THE SCHLICKEYSEN METHOD OF MAKING PEAT COAL

net cost of $2, or 8s., per ton, or into artificial coal having a thermal value of 6250 calories at a cost of $2.50 (10s.) per ton. It is understood that a large plant is in process of erection on the northern coast of Germany for the utilisation of this method; but as to the actual condition of the enterprise or the practical value of the process on an industrial scale, no exact information is at hand.

The Schoening Fritz process for making artificial coal and briquettes by carbonising dried peat is an elaboration by a German engineer of the system invented by Schoening and used with more or less success at Stamsund, in Norway. The German patent is owned by a corporation known as the Deutsche Torfkohlen Gesellschaft, which has its office in Berlin and a small plant at the suburban town of Halensee, where two machines of small capacity,—one worked by hand, the other by power,—have been set up for experimental purposes. The briquettes are made from ordinary brown peat, and are coal black in colour, firm in structure, glazed on the surface, clean as wood to handle, easily kindled, and practically smokeless when burned in an ordinary grate or stove.

Drs. Brockhoff and Ehrecker, of Magdeburg, who as experts analysed samples of coal made by this process, reported that it contained 68.03 per cent. of fixed carbon, 4.98 per cent. of hydrogen, 5.34 per cent. of moisture, 19.89 per cent of oxygen, and 1.76 per cent. of inorganic ash, and had a thermal value of 6205 calories. The process consists in compressing dried peat between hot rollers, by which it is simultaneously carbonised and transformed into coal. According to the statement of the inventor, 1 ton (20 cwts.) of dried peat, costing in Germany about 1.60 marks, will produce from 12 to 15 cwts. of peat coal. To make 1 ton of coal the cost is 2.67 marks for dry peat; adding 1 mark for labour, the net cost of material and labour for producing a metric ton of peat coal would be 3.67 marks. These, be it remembered, are the estimates of the owners of the process, based upon expert tests and laboratory experiments. They are given as notes of progress in the manufacture of artificial fuel in Germany, but they will have a practical interest only when the process has been successfully and continuously worked on a commercial scale.

Of the processes actually employed, the value of which has been fully established by experience, one of the most interesting is that invented by Mr. C. Schlickeysen, of Rixdorf-Berlin, and practically operated there, at Munich, and other places. The peculiar feature

of this system is that by it black, dense briquettes of high caloric value are made from peat without the application of heat,—simply through the action of kneading and drying.

The illustration on the preceding page shows a machine of this type in operation, the raw turf coming up by an endless belt or elevator running in the long, sloping trough which leads to the peat bed,—for these machines are portable and are generally carried on temporary railway tracks, laid so as to enable the machine to follow the point of excavation as the peat bed is gradually exhausted.

Leaving the elevator the raw material drops into the machine, where it is cut, torn, kneaded, and compressed into about two-thirds of its original bulk, and delivered at the end of the machine in cubes of any desired size, which are first dried until they lose about two-thirds of their water, when the drying process is generally completed by artificial means.

The principle upon which this machine operates depends upon the fact that peat in its natural condition contains about 80 per cent of water, of which four-fifths are held in mechanical suspension between the hairy vegetable fibres of which the peat is composed, while the remaining one-fifth is contained in the fibres themselves, each of which is a minute hollow tube, in which water is held by capillary attraction. In the ordinary process of drying peat the material is cut into cubes and laid in the air. Most of the water held between the fibres soon runs out by gravity or evaporates. That which is contained inside the fibres is much more difficult to expel, and for this purpose the fibres must be cut, torn, and compressed until they give up their liquid contents. Nine cubic feet of raw peat are thus condensed by the machine into 6 cubic feet of prepared peat, which still contains about 40 per cent. of water, and this is further dried and compressed into 1 cubic foot of black, dry, fossil-vegetable stone, of about 1.5 specific gravity, which can be sawn, planed, and even polished like cannel coal.

Turf briquettes ordinarily contain about 66 per cent. of inflammable elements, the remainder being made up of inorganic ash and water. They are thus inferior as fuel to briquettes made from brown coal, which average 70 per cent. or more of inflammable matter. Both represent in their present form the utmost that science has been able to do in utilising inferior and otherwise almost worthless materials to supplement and eke out the insufficient coal supply of European countries.

THE PREMIUM SYSTEM IN THE BRITISH ENGINEERING TRADES

By a Staff Correspondent

AN important new departure has been made in the British engineering trade by official recognition of the premium system by organisations both of masters and men. The following letter has been forwarded by the officials to the members of the Engineering Employers' Federation:—

"The question of the introduction of the bonus or premium system into the workshops of certain federated firms, and the difficulties which had arisen in connection therewith, came up for discussion at a central conference held at Carlisle, on August 19 and 20, with the Amalgamated Society of Engineers and the Steam Engine Makers' Society.

"The question had previously been discussed in local conference, but no settlement had been reached. The outcome of the discussion in central conference was a general understanding by

which any federated firm is free to adopt this system of remunerating their workmen.

"The result was embodied in a signed memorandum, which was exchanged between parties, and of which a copy is appended. Your special attention is directed to the terms of this document. As you will observe, it may be found desirable, after experience has been gained, to supersede the present arrangement by a more complete agreement."

The following is the memorandum referred to:—

"Bonus or premium system of remuneration. Memorandum exchanged between parties at central conference, held at Carlisle on August 19 and 20, 1902:—

"The representatives of both parties being of opinion that instead of dealing with each of the foregoing cases (four cases where there were disputes) separately, it was desirable to come to a general understanding on the bonus system, it was mutually agreed:—

"1. That the employers' representatives should convey the terms of the following memorandum to the members of the Federation; and

"2. That the representatives of the Amalgamated Society of Engineers should, on the other hand, remove all restrictions to the working of a bonus system in federated workshops.

MEMORANDUM REFERRED TO

"The employers' representatives have not the power to settle the conditions which should be observed in connection with the working of a bonus system without having previously obtained authority from the Federation in proper form.

"They are prepared, however, to advise all employers, who wish to establish such a system in the meantime, to adopt the following suggestions:—

"1. The time rate of wages (for each ob) should in all cases be paid.

"2. Overtime and night-shift to be paid on the same conditions as already prevail in each workshop.

"3. A time limit, after it has been established, should be changed only if the method or means of manufacture are changed.

"4. No firm should establish the bonus system without intending to adhere to it."

A similar communication was made by the officials of the Amalgamated Society of Engineers to the branches of the society, as we shall presently show. The only objection to the plan is by those men who, broadly, but erroneously, regard it as only a modified form of piece-working. These men, of course, require only a little education to see the truth.

Mr. Fred W. Taylor's paper on the piece-rate system published in CASSIER'S MAGAZINE for October, 1895, was one of the first to draw attention to the system, and also one of the best on the subject; but the plan Mr. Taylor described is not suitable for all purposes of engine manufacture, and especially in such many-pieced work as that of marine engines. The ordinary piecework system has objections which were well expressed some time ago by Mr. Slater Lewis in substantially the following manner:—The piece-work system as usually employed does not commend itself as a satisfactory solution of the problem. An immediate definition and limitation of cost is obtained along with a strong and direct inducement for the employee to exert his best endeavours to increase and intensify production. This is the theory, but in practice it is true only within narrow limits. When once the workman has begun to derive a profit from the transaction, the employer has no direct interest in his further exertions, but only the indirect advantage of a stationary labour-cost coupled with a greater intensity of output.

There comes a time when the gains of the workmen appear excessive compared with his former earnings as a mere supplier of labour by the hour. A reduction of rates follows. But where much piece-work is in vogue, as soon as the workman finds himself approaching the point at which his extra earnings tend to rise beyond the limit at which the traditions of the shop teach him that

reduction may be expected, his efforts slacken. He makes no endeavour to improve for the better management and handling of his job. His interest for the future is barred, and the net result amounts to this, that he has adopted a somewhat greater intensity of production and receives a somewhat greater constant remuneration than when he was on hourly wages. There is a gain in this both to man and employer, but the method is remarkable for what it wastes, as well as for what it effects.

Now the premium system includes all the advantages of the piece-work system without its disadvantages. It provides that a man shall not only be fully paid for all the work he does in an ordinary way, but also that he shall be paid extra for special exertion or individual dexterity in saving time. Broadly speaking, the premium which the Employers' Federation have in view is that formulated and adopted by Messrs. David Rowan & Co., of Glasgow. A summary description of the Rowan premium system is, therefore, necessary to the situation. To begin with, work, recorded on a "job ticket," is given to a workman at Rowan's on a time allowance, and if he reduces this time allowance his rate of wages per hour while he is working at the job is increased by the same percentage as that by which the time allowance has been reduced. Data must be collected for the purpose of arriving at the time to be allowed to do work. For this purpose a special department is required, and, when instituted, data accumulated very quickly. The period occupied in doing work under the usual time payment conditions is practically the time allowance of the premium system. When a job is given to a workman a job ticket is issued to him with a description of the work to be done and the time allowed to do it. On completion of the work the job ticket is initialled, and the time of day recorded on it by the foreman, and this is the time of commencing the next job. When the work has been examined and passed by the works inspector the job ticket is handed to the rate-fixing department, which passes the same for payment. If the job is rejected by the inspector, any premium which would otherwise have been earned by the workman, by reason of his having reduced the time allowance, is forfeited. No clerical labour devolves upon the workmen, and very little upon the foremen.

The time allowance for a job given to a workman rated at 8d. per hour is, let us say, 100 hours, and the actual time occupied on the job amounts to 75 hours. Then 100 hours at 8d. = 800 pence against 75 hours at 8d. + 25 per cent. (2d.) = 750 pence, giving the workman a premium = 150 pence or 2d. per hour, and the employer a reduced cost = 50 pence. The time allowances are equitable to both employer and employed, and, based on the average attainments of hourly labour, it will be evident that the higher the premium earned by the workman the greater will be the saving in cost. The output of the machines is also increased, and this means an appreciable saving to the employer.

A piece of work may be begun on one machine and finished on another. The job ticket in a case of this kind is passed by the first to the second operator, and so on until the work is completed, each workman engaged upon it receiving any premium earned in proportion to the total reduction of time made in completing the whole job. Any number of men may be employed on the same piece of work, and it is not necessary that they should all remain at the work for the same period, because a lump time allowance is made to cover the time of all the men on a job, and the total time spent upon the job fixes the premium percentage, which is used in fixing the premiums of the different men only to the extent of the time each has been employed upon the work.

Thus, a job for which the time allowance is 1000 hours may be performed in 800 hours, and one man might work 100, one 300, and one 400 hours. Each of these men would have his hourly rate increased to the extent of 20 per cent. for the time he had been employed upon the job. The reduction or increase of a workman's hourly rate is not affected,

as any change made during the time he is engaged upon a job is calculated at a percentage on his hourly rate or rates. No difficulty is introduced in respect to overtime allowances, as the actual time worked upon a job determines the time upon which a premium is paid. Overtime allowance does not appear in the job ticket as time, but is shown as such in the workmen's time and wages book as a unit to fix the value of the overtime allowances. In the job ticket this allowance appears at its value in money. Nor is there any difficulty presented when working a night shift, as each of the two men at a machine receives a share of premium earned in proportion to the number of hours worked on the job.

It is advisable that every man should work on his own account, but cases occur in which the inclusion of several men on one job ticket cannot very easily be avoided. In the erecting department the apprentices in their first year are not given a job ticket. In their second and third years they are junior apprentices, and half the time they work is counted; in the fourth and fifth years they are senior apprentices, and three-quarters of the time they work are counted. They are allowed the same time as a journeyman. In the machine department apprentices in the fourth and fifth years do the same kind of work done by journeymen, and they are allowed 25 per cent. more than journeymen.

The payment of premiums does not take effect until 5 per cent. premium has been earned, and thereafter only in multiples of 5 per cent. The original time fixed upon as a time allowance has never been reduced unless there has been a change in the method of doing a piece of work. The premiums earned by the men have generally increased since the introduction of this system, sometimes due to their industry, skill, or intelligence, and sometimes due to those exercising a controlling power. The value of this premium system is not limited to a saving in cost of labour by the reduction of the time taken to do work; it has been the means of bringing to notice improved methods of manufacture.

Another feature is the use of the "job progress card." This card is prepared every morning by the rate-fixing department and indicates the progress which has been made at the various machines, and it may be made of great value to employers and managers. The first column gives the machine numbers; the second column, the hours allowed for the jobs in hand; the third column, the number of pieces included in each job; the fourth column, the hours spent upon the job in hand till 10.30 A. M. on the date the card is prepared; and the fifth column, the previous records for similar jobs. The card is thus an index of the progress of work on each and all machines in operation.

There is also a "job register book" for the machine, brass-finishing, tinsmiths' and smiths' departments, erecting in the works, and fitting on board the machinery in the yard and at the quay. As new jobs occur, they are duly registered. Every separate job is registered in this book.

The "job data book" is a record of the work done on each article, and this book contains a complete collection of data in connection with the manufacture and of other work. All whitewashing and painting, shifting of machines, laying down concrete floors, shifting of material from place to place, and many other operations are recorded in the job data book.

The Rowan system is by no means a final solution of the piece-work problem, but it is regarded as a step towards a solution. The value of good and powerful tools is forcibly brought forward, the use of jigs, gauges, etc., is found to be necessary, and old machines are placed at their true value. Meetings with managers and foremen for the discussion of questions arising in the course of manufacture are found to be necessary and of great value. Better wages are earned by workmen, and more work and better work is got out of the machines. In Messrs. Rowan's works, where the premium system was started at the time of the great strike of 1897-98, there was, at first, objection offered by union men, who complained probably of slavery.. But it was steadily taken

up by others, until it is universal in the engine shop. Experience shows that the more the men work steadily under the system, the more does the premium grow. It is now no uncommon thing for an operative to increase his regular weekly pay by 50 per cent. in premiums.

As to Mr. Slater Lewis' statement, the following points are answered by the Rowan system:—

(1) "A minimum standard of remuneration, based on the average attainments of hourly labour."

This statement is answered by the fact that no matter how long a man takes to do the work, whether from novelty, misfortune, misadventure, hanging over his work, or carelessness, he receives his hourly rate of wages.

(2) "Free and full incentive to the workmen to improve upon this average, not merely up to a certain arbitrary stage of improvement, but without limit." This statement is answered very fully. If a man is repeating the same job on the same machine and is continually reducing the time of production, by all means encourage this man to continue doing so.

(3) "Participation of interest between employer and employee in this improvement, not merely in its early stage, but to the ultimate extent to which the intensification of output and consequent reduction of costs per piece can be carried, either by constantly augmenting manipulative skill or by a series of small improvements in method."

If the time allowance has been fairly fixed at the beginning, the more a man earns, the cheaper is the work. The element of participation is introduced.

We give now the terms of a plan recently started by another Scotch engineering firm. We are not permitted to give the name, but we draw from a statement prepared for the information of their men.

Each man is paid a regular time rate of wages, but when a job is given out, a certain time is allowed for each operation to be completed. If the operation is completed in less time, the employee becomes entitled to a premium, varying in amount with the time saved. It will be evident that while the employee may increase his wages, he cannot lose money by the introduction of the system. The system possesses the two main advantages:—

(a) That it enables a workman to increase his wages by his own individual effort, and the increase is immediately added to his wages.

(b) The increased wages to the workman mean also a reduced cost of production to the employer, and hence there is no inducement to cut rates.

The details of the system as introduced in this particular with it are as follows:—

The amount of premium will increase the rate of wages earned in direct proportion to time saved by increments of 5 per cent. For instance, suppose four hours be allowed in which to complete an operation and it is completed in two hours. The time saved is 50 per cent., and the premium would thus be 50 per cent. of the wages due, *i. e.*, if the rate of pay be 6d. per hour, the employee would receive 6d. plus 50 per cent. premium, equal to 9d. per hour; or, if the same operation was finished in one hour, the time saved would be 75 per cent., or three-fourths of time allowed, and the rate earned would be 6d. plus 75 per cent., equal to 10½ per hour.

The following conditions are to be observed:—

(1) The time allowed for any job will be fixed by the management, and will be, as near as can be ascertained, the actual time which an average workman would take to complete the work. Should it be found to be understated, it will be reconsidered before a similar job is again put in hand; but except in special circumstances, such as the introduction of new and improved machinery, new methods of working, or an obvious error in calculation, the time allowed will not be reduced. There will thus be every inducement to the employees to do the work in the least possible time.

(2) The time allowed includes all time necessary to procure tools, set up machines, and obtain material for doing the job; but, of course, in the case of

any extraordinary cause of delay the time so lost will be added to the time allowed.

(3) All work will be checked and passed by the foreman or shop inspector before being accepted, and the premium will be paid only after the work has been found satisfactory. In the case of dispute, the matter is referred to the management, whose decision will be final as to quality of workmanship.

(4) In the case of overtime the premium is calculated on the wages due for the actual time worked without taking the extra half wages into account.

(5) Each employee, before starting to a job, receives from the clerk a "job ticket," which will be returned to the clerk by the workman when the job is completed, and, when it is made up by the clerk, the premium earned is added on to the ordinary time wages.

After explaining the system, the firm make the following general remarks to their men:—

"The largest premiums will, we expect, be earned by those workmen who arrange their works systematically and who keep their tools in good order, and work their machines in a scientific manner rather than by those who 'hash.' It must not be forgotten that in our class of work the standard of quality must be maintained.

"Lastly, we wish to mention that our reasons for introducing the system are the following:—

"1st. To reduce the cost of production of our output. By so doing we expect to be able to procure more work, thereby employing more hands, and also to enable us to meet that competition which is every day becoming keener.

"2nd. To increase earnings. In every shop, so far as we have heard, into which the system has been introduced, it has resulted in a considerable increase in the earnings of the employees. As explained above, it cannot in any case reduce the earnings. A general rise has taken place due to the premiums, and it is our earnest wish that all our employees should receive the highest wages possible.

"3rd. To stimulate the employees to take a greater interest in their work. With an immediate prospect of deserved reward, we are certain that better methods of doing many jobs will be devised.

"4th. To sustain and improve the efficiency of our plant. The system will, we believe, lead to the employees suggesting improvements and pointing out defects in machinery and tools which can, and should, be immediately remedied.

"We trust that the scheme will meet with the hearty co-operation of all. Difficulties are sure to occur at first, but with a little forbearance and patience these will be overcome, we think, to the advantage of all."

The announcement of the Carlisle agreement was made to the engineering employees by Mr. G. N. Barnes, the general secretary of the Amalgamated Society of Engineers, in an official report. He stated that an important memorandum of agreement has been drawn up and signed by representatives of both employers and engineers which will settle for the time being the question of the premium bonus system that some employers had decided to introduce into this country. The system, he says, has been in existence in some parts of America for a considerable period, and an attempt was made in Leeds to get it adopted, with the result that a strike took place.

Other attempts at its introduction into this country were also made by Messrs. Armstrong, Whitworth & Co., Limited, Newcastle-on-Tyne; the Central Marine Engine Works, West Hartlepool; Messrs. Richardsons, Westgarth & Co., Limited, Hartlepool; and Messrs. Browett, Lindley & Co., Limited, Patricroft, Manchester. In consequence of these attempts a conference was held between the executive committee of the Amalgamated Society of Engineers and the executive committee of the Engineers' Federation. Before the questions affecting these firms in particular were discussed, however, it was suggested that the best way out of the difficulty would be to decide upon the working basis on which the system should be

carried out, and the representative of the workmen, whose object was to prevent an indirect reduction of wages taking place, agreed to this course, with the result that the representatives of the Amalgamated Society of Engineers decided, on the one hand, to remove all restrictions to the working of a bonus system in the federated workshops, while the employers' delegates, on the other hand, though they had no power themselves to settle the conditions which should be observed in connection with the working of the system, agreed to recommend that wherever the system is adopted the time rate should always be paid as a minimum, that overtime and night shifts should be paid for in the same way as they are now paid, that a time limit on any job (once it has been fixed) shall not be altered unless the method or means of manufacture is changed, and that no firm shall establish a bonus system without intending to adhere to it.

Mr. Barnes and his colleagues, in recommending the adoption of the agreement, pointed out that the fact that time rates are to be the minimum payment for any job will prevent any unscrupulous employer or foreman from placing the time limit so low that the ordinary workman will lose on one job all the benefits he may get on another by receiving a bonus on the amount of time he has saved upon it. The second condition imposed assures to the employee extra rates for overtime and night shift. The third clause will prevent an attempt to cut prices once a time limit has been fixed; and the last clause is framed with a view to preventing firms making experiments with the new system just for the sake of seeing how it will work.

In a later number of the society's *Journal* Mr. Barnes reports to the Amalgamated Society of Engineers that "many resolutions have come to hand" respecting the Carlisle agreement on the bonus system, "and considerable excitement appears to have been vamped up in relation thereto." The Council is blamed for signing the agreement without authority,—against even the protests of colleagues. Mr. Barnes says that these statements are "quite untrue." He points out that the employers had the right to introduce the bonus system and that what the Council did was to safeguard the interests of the society under it. The point is pressed home in a circular which has been issued to branches, and instructions are given that if any member refuses to work under the conditions laid down by the Carlisle Conference donation benefit is not to be paid to him. This is a strong feature in the situation.

Mr. Sidney Webb, who supports the premium plan, is strongly opposed to the piece-work system, concerning which he wrote recently as follows in the *Engineers' Monthly Journal*:—"Unregulated by any definitely established list of prices, and beyond the reach of collective bargaining, competitive piecework inevitably leads to degradation and sweating. However specious it may seem at the outset, it is diametrically opposed to the standard rate,—the principle of equal pay for equal effort. Any attempt by the employers to introduce such a system should certainly be resisted as contrary to the teachings of experience, disastrous to the workman's standard of life, and really, in the long run, no less injurious to the employers than to the operatives. No one with any knowledge of the past experience of such a system, or of its actual working in other trades, would dream of introducing it. In resisting it the men have political economy on their side."

We do not altogether agree with Mr. Webb either in this or in what he goes on to say about time payment.

"It is," he says, "when you come to think of it, essentially the method of the slave-owner. It in no way secures equal pay for equal effort,—the standard rate,—but only equal pay for equal time, which is a very different thing. It always leads to suspicion, even when not actual cheating. The employer is never quite sure that he is getting from all the men in the shop a fair amount of energy in return for his wages. He is naturally apt to protect himself by incessant supervision and 'tasking,' sometimes ap-

proaching tyranny. What is no less objectionable from the point of view of the trade unionist is that payment by time is a most unscientific and inaccurate method of remuneration.

" The essential principle of trade unionism is the maintenance of the standard rate of remuneration for effort. Without a fixed and accurately-defined standard rate of equal pay for equal work no successful collective bargaining is possible. But with time wages only the standard of pay is defined, not the standard of effort. Thus, for the collectively agreed rate of a shilling per hour, one workman may be giving twice as much effort as the normal standard adhered to by his colleagues. Another may be giving only half as much as that normal standard. The first is undermining the standard rate, upon the maintenance of which the welfare of himself and his own class depends. The second is meanly defrauding his employers, to the discredit and dishonour not of himself alone, but of the whole wage-earning class."

After considering various methods of remuneration, Mr. Webb concludes in favour of the premium plan, thus:—

" For definite piece-work statements in the engineering trade neither employers nor workmen are yet prepared. Under these circumstances the premium bonus system, provisionally agreed to, seems to me an admirable expedient. The Amalgamated Society of Engineers may, in my humble opinion, safely agree to it. The standard time-work rate is fully protected. The danger of a future cutting of rates is well guarded against. As it is, the first-class firms who are desirous of adopting the system, not the producers of ' cheap and nasty ' work, the necessity of attracting and maintaining first-class workmen (who will certainly not continue under the system unless they make top wages) enables us, in my judgment, to dismiss this fear. And, what to my mind is a great advantage to trade unionism in the engineering trade, the system makes a distinct advance in rendering more accurate and scientfic the working of the standard rate itself,—the securing of equal pay for equal effort."

And on the fallacy about the displacement of " mates " by doing premium work Mr. Webb writes:—

" The only objection that I have heard to the premium bonus system is that it will lead to more work being done in a given time, with the result, as is imagined, of throwing some men out of work. But this is really a gross fallacy. If every member of the Amalgamated Society of Engineers turned out 25 per cent. more work, and was duly paid for it, this would be to the advantage of all the men, as well as to that of the employers and the whole community. There is no fixed quantity of engineering work to be shared. The demand for machinery of every kind is indefinitely expansible, and grows every day with every lowering of price. The better the engineers work, the more they make, the greater the amount of engineering work to be done, and the more numerous will be the men employed. If throughout the whole world every man's labour was suddenly rendered half as productive as it now is, we should be worse off, not better. So if every man's productivity were suddenly doubled, we should all be better off, not worse."

And Mr. Webb's strong and earnest advice to the engineers is to ratify the provisional agreement which their Executive Council has secured. It will take a little time to get into common operation, but the common acceptance of the principle of the premium system seems the beginning of something like an industrial revolution.

LABOUR UNIONS

THEIR GOOD FEATURES AND THEIR EVIL ONES

By President Charles W. Eliot, Harvard University

From an Address Delivered at the Colonial Club, Cambridge, Mass, U. S. A.

I WANT to speak of labour unions from the educator's standpoint. What is that standpoint? I belong to a class of men who are employed under humane conditions. University teachers in general are employed under humane conditions, and in that calling I have been both employed and employer,—indeed, I combine these functions to-day. I admit, however, at once that the point of view of the educator is a peculiar one. He is a man devoted to systematic education, which means devoted to a continuous process intended to transmit the accumulated learning and experience of former generations to the rising generations as they succeed each other, and, therefore, to a process of gradually uplifting the human race, or that particular portion of the race to which he himself belongs.

It is natural, therefore, for one whose profession is education to sympathise with other efforts to uplift the race, to make the lot of average mankind more satisfying and happier. That being the ultimate object of education itself, an educator necessarily sympathises with other broad efforts to produce the same result that he seeks. Among these must be counted the work of the labour unions. They heartily believe that their work tends to uplift the labouring classes. They heartily believe that even when they engage in industrial warfare their object is to raise their class, though at present sacrifice. This belief is their strength.

It is, however, clear that education is not the primary instrumentality of civilisation. The primary instrumentality is work, regular, daily work. On that must be founded all other instrumentalities for uplifting mankind. This clearly appears in the history of our race. No savage people, no nomad tribe, can be lifted into civilisation until it adopts as a habit regular, daily, settled work. The same is true with every individual. It is of no use to try to teach children to read and write if their parents belong to the Stone Age.

It is of no use to try to educate the children of a tribe which is nomadic, without settlements, without home. Education, therefore, is a secondary instrumentality, habitual labour coming first. Hence the importance of humane conditions of employment, of humane conditions of the daily labour by which the millions are supported,—the daily labour which forms the groundwork of the civilisation of the people.

And now, what are humane conditions of employment? That is a question on which the experience of university men sheds some light. Naturally enough the conditions of university employment are humane in all civilised nations. Indeed, I believe them to be the most humane in the world. Now I am going to try to state what I think to be the humane conditions of employment, basing my delineation on my own experience of university employment.

The first of these humane conditions I conceive to be a rising wage, that is, a wage which gradually,—it need not be rapidly,—increases with the labourer's increased experience, attainments and age. This condition means for the labourer hope, expectancy, recognition

of merit, and gradually increasing reward of merit. It seems to me that this rising wage should be regarded as an essential condition of satisfactory employment.

The second universally desirable condition is steady employment, after adequate probation. I have never seen any hesitation on the part of young men in accepting a reasonable probation, and every intelligent person wants steady work. Yet that method of steady employment after adequate probation can hardly be said to exist in the ordinary industries of the civilised nations. It applies dismissal only for cause,—for plainly visible, indisputable cause. It also implies, on the part of the employer, a perfect readiness to deal justly and fairly with complaints. I believe steady employment to be the sound condition for national human development in all walks of life. It is the steady job which develops fine human character, and, on the other hand, spasmodic employment is a very unfavourable condition for the development of character. It may seem strange to you even to mention such a reasonable opportunity for the development of character as steady work among conditions of employment. We certainly are not accustomed to that view. But is it not, after all, the only rational view of humane conditions of employment?

A third humane condition of employment I hold to be encouragement for the making of a permanent home. That is just what the university conditions of employment encourage. The making of a permanent home means that the home creator has opportunity to form local attachments, to evince public spirit, and to win for himself local reputation among his neighbours. Neighbourhood reputation is the most rewarding kind of reputation. These aids to the development of character and these sources of happiness the normal workman loses completely. Therefore, a wandering, unattached condition for labour is always unhappy and inexpedient, whether we regard the interests of the individual or the interests of society.

Fourth, among humane conditions of employment I put the opportunity to serve generously and proudly the establishment or institution with which the labourer has been connected. That is a high privilege for any human being. It takes him out of himself, and gives him a happy motive for fidelity and zeal. You observe that this opportunity cannot be had unless employment is steady and the home permanent. This is a satisfaction which all university men win. It is a delightful part of the university man's life, a privilege to be accounted much higher than large salary or any form of luxurious living. It is one of the deep, permanent satisfactions of human life; and I should not call any conditions of employment humane which made that satisfaction unattainable by the humblest labourer.

The fifth right condition of employment is the pension on disability. It gives security and dignity to the labourer; it gives throughout life relief from one great anxiety; it gives also that public consideration which goes with a steady job and a self-respecting, though humble or unobserved career.

Now there are five conditions of humane employment, which I believe to be not theoretical or fanciful, but perfectly capable of realisation. But I think we shall have to confess at once that these are not the common conditions of employment in those large industries which require the services of multitudes of comparatively unskilled labourers.

To-day the large services in which these principles are adopted are few in number. I remember hearing an eminent railroad president say, ten years ago, that there was only one rule on which railroad service could be conducted, and that was the rule of instant dismissal. Instant dismissal characterises many employments to day.

Another serious difficulty with American employment is that it is spasmodic. In almost all the large services it is not steady, but spasmodic,—first a rush, and then an absolute stop. Again, in most industries,—not all, I am happy to say,—complaints are not listened to, or, if listened to, are made ground for dis-

missal. That is profoundly unreasonable as a method of administration, and is an abundant source of bitterness and discontent. Also, there are no pensions except in a few fine services, which are beginning to illustrate the proper conditions of employment. Moreover, wages are fluctuating. Steadiness of wages, however, is an immense object to all wage-earners.

Under such circumstances, then, labour unions have grown up among us. They have become more and more aggressive, and are likely to extend constantly their fields of operation. Against them are arranged the employers, and sometimes the non-union men. Whose fault is this condition of industrial strife? It is clearly the fault of both parties. But it seems to me that the employers may justly be held more accountable than the employed. On the whole, the situation of the employers is generally more comfortable, their education superior, their intelligence greater. Under these difficulties and with these justifications labour unions have been organised and have struggled with more or less success toward their remote good.

Before I take up the points at which I find labour unions to be ill-advised, let me admit, as all persons must who have studied their history, that the industrial community as a whole is under many obligations to the unions. They have, as a matter of fact, mitigated many evils. They have reduced what used to be the unreasonable number of hours in a day's work. They have improved health conditions in factories and mines, and have procured the legislation which has enforced better health conditions. They have prevented young children from working in factories, and they have emancipated employees in many industries from the company store. Moreover, they hold in check combined capital; and combined capital is, from the democratic point of view, a formidable oligarchy. The labour unions hold that oligarchy in check.

The argument commonly used in justification of the organisations of labourers in unions is a sound one,—capital is effectively combined in certain industries, and, therefore, labourers must effectively combine in those industries. That argument is unanswerable. The great combinations of capital are very formidable to unskilled labourers,—much more formidable than to the average man in the community at large, and they are sufficiently formidable to us all. I think, too, that we all believe that the labour union is going to last. The facilities for uniting multitudes of men in one organisation, for communicating on the instant with all branches of the organisation, for bringing masses of men together for a common purpose, have increased wonderfully even within the last ten years.

In view of this situation it is manifestly important to discuss frankly and publicly any labour union doctrines or practices which seem dangerous to society or hurtful to the men who adopt them. The first evil is the close limit put on the number of apprentices in shops or factories or mines. This seems to me a strange interference with a fundamental democratic doctrine. It was Napoleon who gave it a very compact expression:—"Every career is open to talent." Now that is a fundamental doctrine, one that we all thought everyone of us heartily believed in. The labour union undertakes to close the trade which it represents from young men. It prescribes, for example, to a great printing office, where hundreds of men are employed, that only an insignificant number of apprentices shall be allowed. I have read many constitutions of trades unions and I have never failed to find in them this disposition to limit education for the trade. It seems to be the common labour union doctrine that the youth are to be kept out of the trade. It is the exclusion of the newcomer for the protection of the old hand.

I need not point out how inconsistent this is with all practices in higher education. A group of eminent lawyers, for instance, devote themselves to educating young lawyers. A group of dentists devote themselves, at pecuniary sacrifice, to training as many young dentists as they can get together, with the result that the young men immediately begin

to compete in practice with their teachers. All through the higher education runs this conception of using a talent for teaching to increase the number of men well taught. It is the same spirit which makes the physician or surgeon always give to the community any medical or surgical discovery he may have made.

It is the disposition among liberally educated men to provide every facility for entrance to the learned and scientific professions The spirit of the educated class is to further to the utmost every process of education which admits to the class, while the spirit of the labour union seems to be the exclusive spirit; it tries to protect the possessor of a trade against the new aspirant.

Another pernicious doctrine held by many unions is the doctrine of limiting the output or day's product of the individual labourer. This doctrine seems to be based upon the opinion that there is a definite amount of demand for the product of any industry, and if that demand is satisfied by a portion of the labourers in that industry there must be another portion who get no work,—who can get no work. If one hundred thousand labourers satisfy the demand when one hundred and fifty thousand are in the trade, the remaining fifty thousand will starve. Generosity teaches that the one hundred thousand labourers should not satisfy that demand, but should work slowly,—say, at two-thirds their natural speed, so that the fifty thousand may have a chance to share the demand. The claim of the union is that the limitation of output has a generous motive,—the motive of permitting those that would otherwise be unemployed to share the fixed demand.

I need not point out that the theory of a fixed demand is in the highest degree improbable; at any rate, it cannot be computed or demonstrated. It is an assumption that it is impossible to prove. But, on the other hand, it is obvious that the effect on the individual labourer of habitually working at a rate below his natural capacity must be thoroughly pernicious. What alert, ambitious man but desires to make his daily output as large as possible, no matter what his calling? What must be the effect on the individual labourer of endeavouring, day after day and year after year, to do less than he might do in the appointed hours of labour? Must it not be degrading? Must it not gradually undermine his own capacity for production? Will he not become, year by year, a feebler and less useful man? The proper ambition for the labourer in any calling is to produce as much as possible, of a quality as high as possible; and no other purpose will foster the development of the best workmen or the best men.

I object, therefore, utterly, to the limited output for the individual, because it fights against the best instincts of the best labourers. It also, of course, diminishes the productiveness of the entire community, and tends to make the whole community indifferent and ineffective.

A third doctrine of labour unions which seems to me to fight against the true developing principles in human nature is the doctrine of the uniform wage. This uniform wage works in two ways; in the first place, it prevents the capable labourer from earning as much as he might, which is not only a misfortune to him, but a misfortune to society; and secondly, it is cruel to the inferior workman. The labour union establishes a uniform wage at as high a level as it can, and in every trade there will be many workmen who really are incapable of earning that wage; that is, they cannot satisfy the employer in the unionised shop. He finds that he is paying some of his men a wage that they can earn, and others a wage that they cannot earn. How does he protect himself? He gets rid, whenever he can, of the labourer that cannot earn the wage named by the union. The consequence is that the inferior workman cannot earn in a year any adequate wage, since he is often unemployed. This is one of the greatest cruelties of labour unions. The inferior workman, if permitted to work at lower wages, might be steadily employed. He cannot be steadily employed when a wage must be paid to him which he cannot earn.

There is, of course, another aspect of

the uniform wage. In times of pressure, which occur frequently in all industries, many men are taken on at the union wage who cannot earn it, and the employer suffers very serious loss in the process. This, however, is a totally different aspect of the same false method. The uniform wage, in short, works badly in all directions. It is a discouragement to the capable workman, it is a cruelty toward the less capable, and from time to time it inflicts great injury on the employer.

I come now to a fourth objection to the labour union,—its teaching in regard to the use of violence during a strike. This is a doctrine which is not always avowed; in fact, one of the most serious objections to the public utterances of labour leaders is that they endeavour to conceal the violence which is actually resorted to. They even deny, in guarded language, that there is violence. In their denial they use the phrase " overt act," for instance, meaning thereby a public crime, like killing or blowing up a house. Now, what is the fact with regard to the use of violence when unskilled labourers strike? I say unskilled labourers, because the unions of highly skilled labourers have another means of resistance. They can rely, many a time, upon the fact that there is no large supply of labourers skilled in their trade; and they are, therefore, not obliged to resort to violence, or, at least, they may avoid resort to violence. But that is not at all true of the union of unskilled labourers.

To enforce a strike, they really have no other weapon but violence, and they all know it, and their leaders know it. They resort invariably to violence within a few hours, and nearly every considerable strike for the past ten years has been accompanied by violence. The reason for this lamentable fact is that violence is inevitable. Such strikers have no other weapons; I suppose most of us have seen this with our own eyes. When a strike occurs on a street railway, for example, there are always hundreds of men who want to take the places of the men who have struck. There is but one way of preventing them from doing so, namely, by violently making it too dangerous for them.

These are but illustrations of a universal fact. Now, what is the theory on which, in labour unions, violence is justified? It is justified. I heard the theory ingeniously stated at a recent meeting of the Economic Club of Boston, and I think I can give it to you accurately. The labourer who has worked in a factory or shop for years, or even months only, has acquired an equitable right in that factory which is not discharged by the weekly payment of his wages. He has made a part of the reputation of that factory and the reputation of its product. He has created a part of the good-will of that factory. This claim is substantial, and it is not discharged by paying him weekly wages.

He joins his fellows in declaring that for a time they do not propose to continue to work in that factory on the conditions which prevail at the moment. He then sees a man taking his place. Now, that man is possessing himself of that equitable claim on the factory of the right in equity which the former labourer has acquired, and which he ought not to lose by going on a strike. The incoming man is a thief and a robber, and he can be dealt with as one deals with a burglar in one's house. The scab, or strike breaker, is a burglar, and if ever violence is justified between man and man, violence is justifiable between the union man who has gone on a strike and the scab who takes his place.

The argument is plausible, but has a fatal, weak spot. It claims a right in the factory or business which depends on continuous operation, and also claims the right to discontinue the business or shut up the factory.

This doctrine I believe to be a dangerous one, and one that combats all principles with regard to freedom in labour. I find that the principle that a man has a right to sell his labour at whatever price he chooses to fix is earnestly disputed. Indeed, it is said that no man has a right to sell his labour at any price, without considering the effects

of his sale on associated labourers in the same trade or business. The right to earn bread for his family by whatever opportunity which presents itself is denied. He must not earn bread for his family without considering the effects which his taking the price he is willing to accept may have on thousands of other men who are not willing to accept that price. This doctrine cuts deep, and the people have got to consider and reconsider this contest of opinions. It is a serious contest of opinions with regard to personal liberty.

The sort of violence which the labour unions justify is various, and there has been a great development in the variety of violence within the last ten years. The inevitable violence now takes the form, first, of a few serious outrages on persons and on property. It does not take many outrages to alarm a considerable population. Three or four assaults, three or four killings, a few blown-up houses, will terrorise a large community. But these operations need not be numerous, they need not be frequent. The more effective method, when combined with these assaults and outrages, is the method of the boycott.

I have not time to describe the varieties of the boycott. Suffice it to say that the boycott, in a community where the union men are in power, penetrates every nook and corner of society. Every shop, every office, every professional man's employment is assailable, and is assailed. But it does not stop there in a community where the union has a large majority. The police, the courts and the newspapers can all be controlled. They have been repeatedly, and they are to-day, in some localities. You see how much ground that covers,—the police, the courts and the newspapers. The community at large is thus deprived of information and the community on the spot is deprived of the ordinary protection of the courts and the officers of the courts.

One step remains to be taken in communities where the labour unions are in command, namely, the control of the militia. We shall probably see during the next few years strenuous efforts, direct and indirect, on the part of the unions to control the militia. There are two ways of controlling it,—fill the local militia with union men, but legislation may also be resorted to; and, thirdly, the boycott will be effective to this end unless the public learns how to disarm it. The formidableness of the boycott, except in a region where the union men are in a clear minority, is a singular phenomenon in society.

The total number of labourers organised in unions of the United States, for example, cannot possibly be placed higher than 2,000,000. Colonel Wright, head of the United States Labour Bureau, says that he cannot place it higher than 1,700,000. It is, therefore, conceivable that the more numerous non-union men, or the public at large, should learn how to control or defeat the boycott. It needs to be defeated. It is a cruel, cowardly interference with the rights of all the people.

Discussion of evils seems to me seldom expedient, unless it leads to the discussion of remedies. Now, there are certain hopeful prognostications for industrial peace. In the first place, whenever either party to the combat gives a demonstration of unreasonableness and folly, that party promotes the adoption of policies which are more rational, and we had that demonstration to perfection from both sides during the recent five months' American anthracite coal strike.

When we reflect upon it, does it not seem wonderful that at the end of this strife about mining anthracite, which in bitterness exceeded the bitterness of many wars, in which measures were proposed and attempted to be executed which in actual warfare people generally abstain from,—as, for instance, the endeavour of the miners to force out of the mines the engineers who kept the mines free from water, while throughout the Transvaal war, surely a bitter strife and a prolonged one, that operation was never resorted to or even proposed by either party,—isn't it wonderful, I say, that at the end of five months of this extraordinary turmoil, this infliction of perfectly unnecessary losses upon the entire community, and especially on

both combatants, we should arrive at a solution which might just as well have been arrived at before the strike began? This is a demonstration, I think, of a gross lack of intelligence in both parties to the strife.

At the end of five months an arbitration commission was appointed,—certainly no better than the two parties could have selected at the beginning. Such irrational conduct on both sides should teach the public that this sort of industrial strife is stupid, and, therefore, to be avoided by more intelligent policies and efforts. It teaches that it is better to confer at the start than to fight first and confer afterwards.

The incorporation of unions is, of course, very desirable, because arbitration between one body which is incorporated and another body which is not incorporated is not perfectly fair. A penalty can be enforced against one and not against the other. But all the labour unions and all the labour leaders, as far as I know, are opposed to incorporation. They dread the action of the courts. They have had many quarrels with the courts, and have often been defeated in them, and they have a natural dread of litigation. The well-kept agreements between incorporated bodies on the one hand and unincorporated labour unions on the other are all the more interesting because they may prove to be the means of gradually bringing about the incorporation of unions when, by experience under these present agreements, the unions learn to trust to a contract. When that trust has once been created, the unions may cease to fear a contract enforced by the ordinary legal methods.

Lastly, I think there are many signs in important manufactures that labour unions can, by good judgment and good feeling, make themselves a convenience to corporations engaged in industrial work. I have lately had conversations with some large employers of labour who perceive the convenience in large industries of being able to procure the assured delivery at a fixed price of any required number of labourers on a contract covering a year or five years. It is interesting to perceive that the urgencies of great business seem to tend already to methods which have been developed in the course of centuries in old China. The Chinese method is the delivery of any required number of labourers by a company for a fixed price. In some respects there is a curious resemblance between the common Chinese method and the method toward which the labour union tends. The union labourer of the future, once involved by the thousand, may be hardly freer than the Chinese labourer, who is delivered to order by the thousand at an agreed price. All the more important is it that joining the union should be completely voluntary.

The first thing needed in every labour trouble is to learn exactly what the difficulties are, and here it must be confessed that there are obstacles. Both parties to industrial strife as a rule distrust publicity. It is a general fact that corporations wish to conceal their methods of doing business, and that labour unions also wish to conceal their reasons for demanding more pay or less work. Therefore, the means of procuring publicity in regard to such matters ought to be diligently sought by the people as a whole.

We have many means of publicity. The local newspaper will not serve us. The great metropolitan newspaper might, the magazines might, legislative commissions might. They do not always, but they might. It is for the people to seek thorough information on all these industrial struggles, and to spread abroad among the people sound notions concerning their causes and their results. Then, I think, we may all hope that we shall find a way through these formidable social dangers.

DEVELOPING A BRITISH WAR POST

AN OUTLAY OF £4,500,000

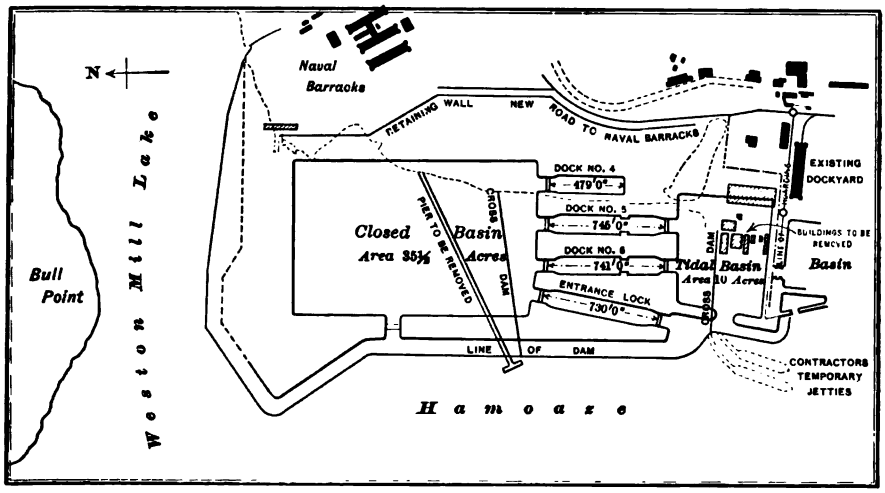
By Archibald S. Hurd

TEN years are a long time in these days to devote to the carrying out of an engineering contract, and over £4,500,000 is a big price to pay for it. This, however, is the period and this the outlay in transforming Devonport into the most vital war port of the British Empire. It is recognised that in case of hostilities in European waters between Great Britain and one or more other European powers the two most probable scenes of action will be off the Land's End and in the Mediterranean. Therefore, in time of war the British fleet will urgently need a convenient port into which disabled ships can put in case of need, where they can be docked and repaired with as little delay as may be.

Merely as a refuge Falmouth will be useful, and this haven has recently been provided with means of defence against torpedo attack,—quick-firing guns and searchlights. But more than this will be needed, and consequently the dock accommodation beside the River Hamoaze at Devonport is being more than doubled at a cost of over four and a half millions sterling.

The most striking defect of the Western Dockyard is that at present it can build larger ships than it can dock. Up to the beginning of 1897 this was not the case, but then the building equipment of the yard was improved and the first modern battleship,—the *Ocean*,—was commenced. On this new slip several even larger vessels have since been constructed. The *Ocean*, of 12,950 tons, was followed by ships with a displacement of 15,000 tons,—the *Implacable*, the *Bulwark*, and the *Queen;* and the *Montagu*, of 14,000 tons, was also built at that yard.

Now the slip is occupied by a greater armoured ship than has hitherto been



AN OUTLINE OF THE PLAN OF EXTENSION OF H. M. DOCKYARD AT KEYHAM
SIR JOHN JACKSON, CONTRACTOR

A GENERAL VIEW OF THE MUD EXCAVATION OVER THE SITE OF THE DOCKS

attempted in any government yard. The King himself laid the keel plate of the *King Edward VII.* in the spring of 1902. This ship will displace 16,350 tons, and her length will be 425 feet, in comparison with 390 feet in the case of the *Ocean.* Her beam will be 78 feet and her draught 26 feet 9 inches. But this, of course, is not the longest ship which may need to use Devonport in time of war and of peace. The *Powerful* and the *Terrible* are each 500 feet long, and this is the measurement for the four new " monster cruisers " of the *Drake* class. At present, the yard can find docking accommodation for nothing exceeding the length of the *Magnificent,* —390 feet,—and hence arose the urgent necessity to increase the docking facilities.

This Devonport project is the greatest scheme of " dockisation " ever undertaken at one time and the largest contract of the kind entrusted to one contractor. As far back as 1896 the task was begun, and one of the docks has just been completed, but the entire work will not be finished until 1906. The scheme presented many engineering difficulties. The Admiralty's plan included the reclamation of eighty acres of the foreshore of the river and the utilisation of about forty acres of adjoining land. On this site Sir John Jackson undertook to make a series of basins and docks,—the latter the largest in the world,—and in the accomplishment of the scheme he has had to solve some problems new to engineers, to enlist the services of a large fleet of specially constructed vessels, and to obtain from his army of 3000 labourers an output of work which has probably no equal in the story of industrial achievement.

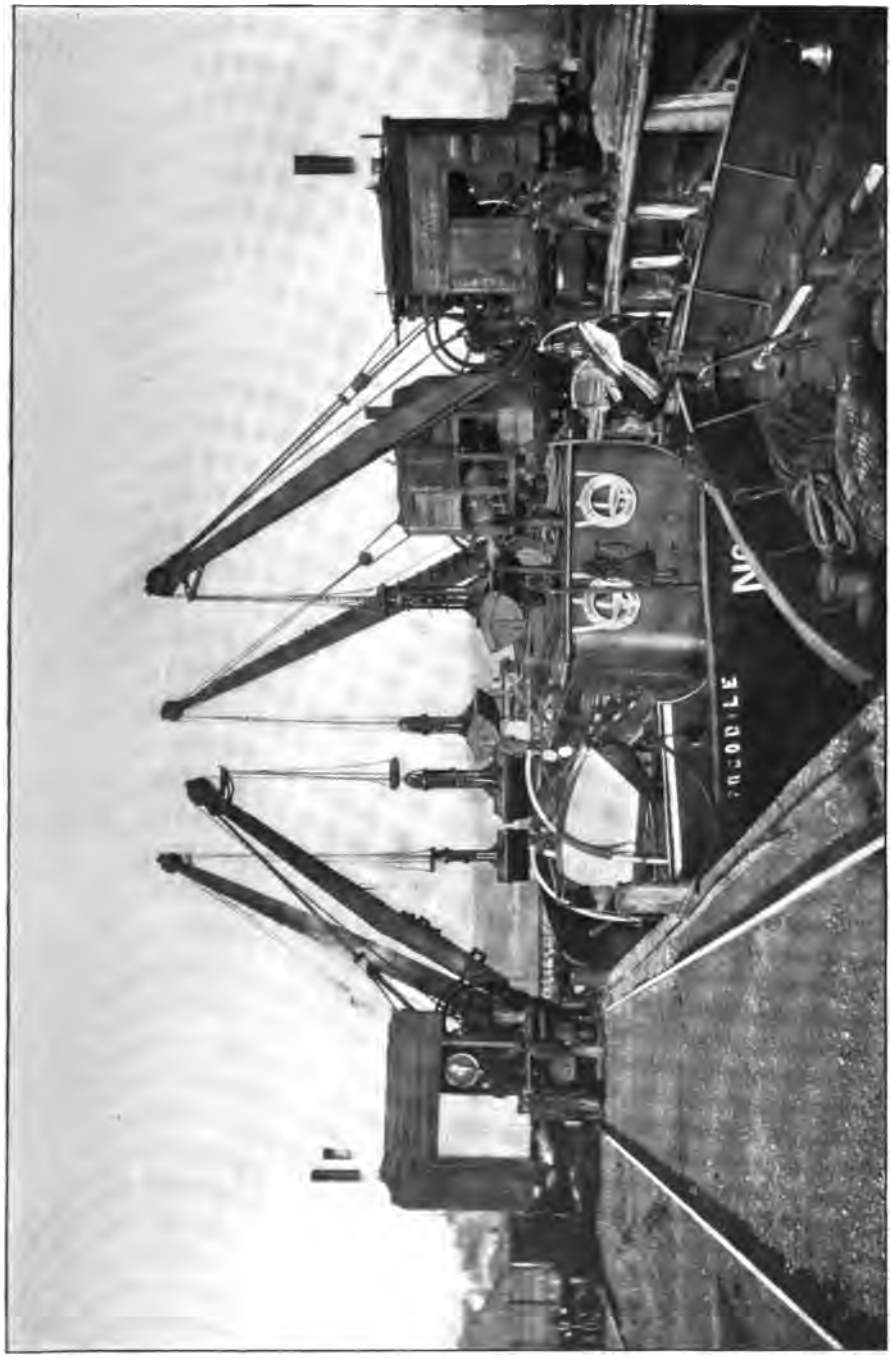
When the original survey was made, the task might have seemed hopeless. The eighty acres of the river foreshore and bed consisted of mud,—deep, clinging mud,—running in some places to a depth of over 90 feet, so soft that it was at once recognised that, even when the river had been hemmed back, it would give no support to such heavy machinery as could most quickly and economically scoop out the basins and docks.

The first task was to get rid of the

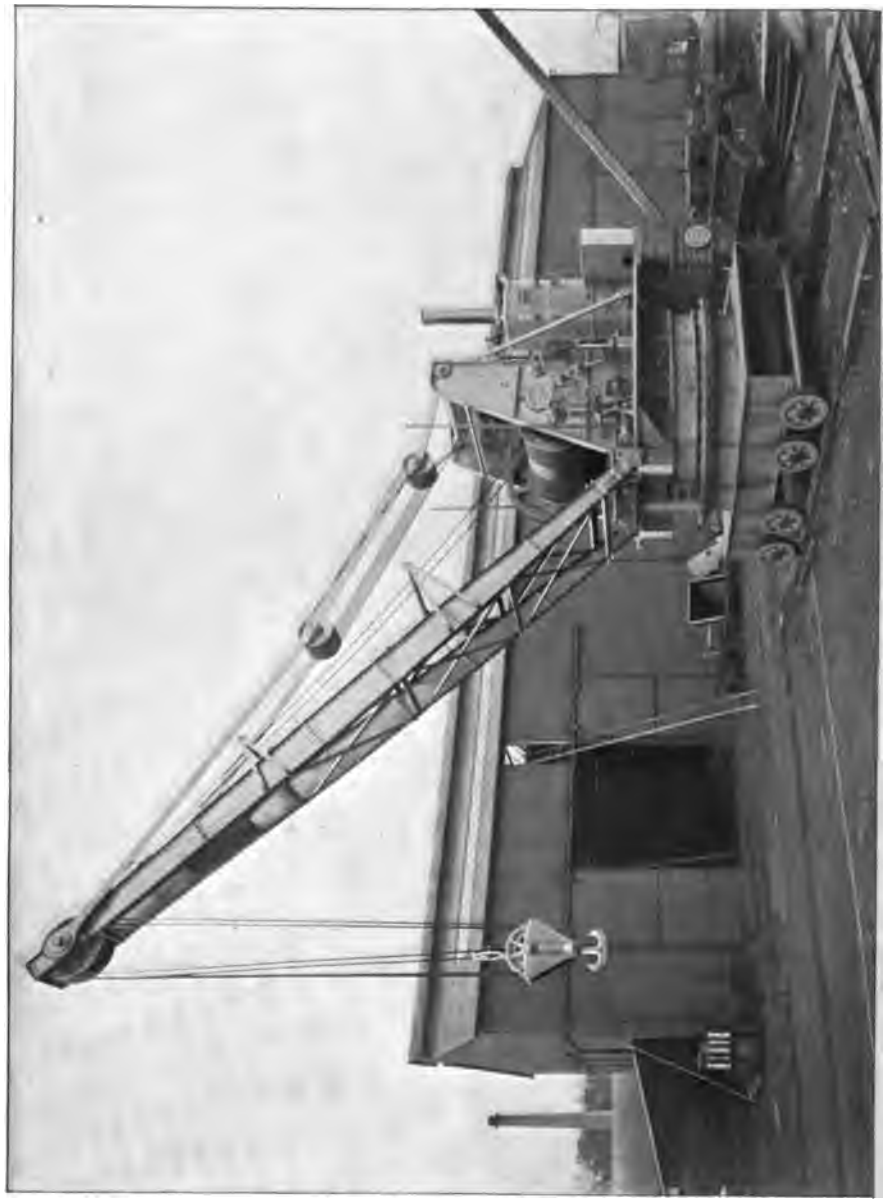
SOME OF THE HOPPERS FOR CONVEYING MUD TO SEA

A LOADING BERTH FOR THE MUD HOPPERS

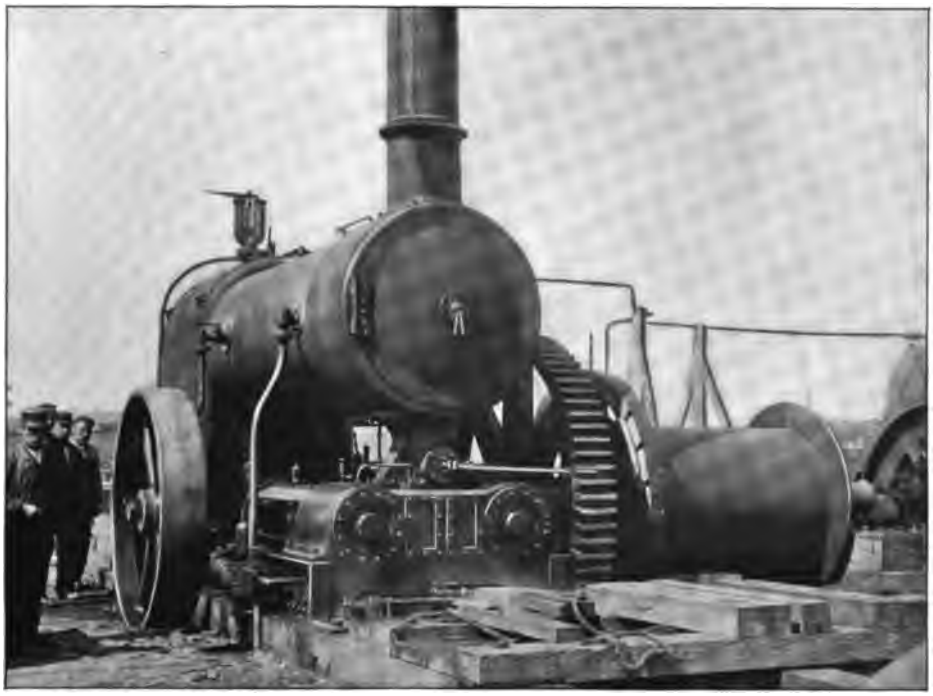
ONE OF THE GRAVING DOCKS. A CONSTRUCTION VIEW



A GROUP OF 10-TON CRANES FITTED WITH HONE'S PATENT GRAB. MADE BY THE THAMES IRON WORKS, SHIPBUILDING & ENGINEERING CO., LTD., BLACKWALL



A 30 TON TRAVELLING AND DERRICKING CRANE, WITH 35-FOOT MAXIMUM WORKING RADIUS, WORKING BY SIDE OF DRY-DOCK FOR LIFTING ARMOUR PLATES AND HEAVY MACHINERY FROM BATTLESHIPS. MADE BY MESSRS. STOTHERT & PITT, LTD., BATH



ONE OF THE 40-H P. HOISTING ENGINES SUPPLIED BY MESSRS. RUSTON, PROCTOR & CO., LTD., LINCOLN

water of the river, and two years were occupied in the construction of a coffer-dam, one and three-quarter miles in length. It consists of timber piles laid closely in a long row and filled in with puddle clay, so as to provide a substantial, watertight wall. Owing to the depth of the mud, these sticks of timber, shipped from the forests of British Columbia, had to be from 65 to 90 feet long. For greater security along the portion of the area of the site most exposed to the action of the tides, a second dam was constructed, and the site was bisected by two other somewhat similar constructions. In this manner over 2,000,000 cubic feet of this timber were used; in other words, if the several sections had been in one line, they would have stretched for a distance of two and three-quarter miles.

While the construction of the dams was in progress, the water had to be allowed to flow in round the works, so as to obviate the pressure of water until all was in readiness, and then the water shutters were closed down at low spring tide and the site was clear for the workmen. It is impossible to compute the cost of this preliminary operation to the actual construction of the docks. It ran into many scores of thousands of pounds, and the irony is that when the works within are completed all these million or more great piles will have to be drawn out,—a task that will be like taking teeth out of some leviathan.

When the main coffer-dam and the subsidiary constructions had been completed, the work on the basins and docks could be commenced, and the enclosed site of 120 acres was planned out so as to provide the following accommodation, apart from the necessary buildings:—

A tidal basin with an area of 10 acres at one side of the ground; a closed basin of 35½ acres at the other side of the site; and between these two great expanses of water, four docks with double caissons, including the entrance

A WILSON 10-TON CRANE WITH A STOTHERT & PITT CYLINDER SINKING GRAB

lock to the closed basin, running straight in from the river.

	Length	Breadth	Depth Below the Coping
Dock No. 1. ..	470 ft.	95 ft.	45 ft.
" 2....	745 ft.	"	45 ft.
" 3....	741 ft.	"	55 ft.
Entrance lock.	730 ft.	"	55 ft.

The feature that calls for remark in connection with these works is not merely the size of the basins and docks, but the great depth of water. As to the first point, the docks are more than large enough to take in the largest man-of-war in existence and then leave over 300 feet to spare in the case of the *two* larger graving docks and the entrance lock, and this length can be increased by 50 or 60 feet by placing the caissons at each end in the outer "stops," while No. 1 dock, which has only one entrance,—that from the closed basin,—and, therefore, only one caisson, can also be lengthened, though not to the same extent.

In the matter of depth the Admiralty have made more than ample provision for future developments, though there is, at present, a tendency towards de-

creased, rather than increased draught in ships of war. No modern warship draws more than 27 feet of water. In the tidal and closed basins the depth from the copeline to the bottom is 55 feet, giving 32 feet of water at low tide. In other words, the biggest ships will be able to enter or leave either of the docks at any state of the tide.

The whole of this accommodation for shipping will be enclosed by a great outer quay wall, 4700 feet long, with a breadth at the base of about 35 feet. This is now being built inside the temporary coffer-dam on a comparatively new system. Owing to the softness of the mud and the danger of the coffer-dam moving inwards, it was deemed unwise to adopt any of the usual methods known to engineers. The first operation consists in casting a huge mass of concrete in irregular rings, each with three large holes. Scores of these masses are made. On the line of the proposed wall these masses are placed one on top of the other. At first their weight drives them down, and as they sink the mud that they displace rises in the holes and is taken out by steam grab excavators.

At last the point is reached when the columns will sink no further in the mud, and then on the top of them is built up a column of heavy rings of iron, and as they exert pressure downwards, the steam navvies grab out the mud from the holes, until at length they will go no deeper and it is found that they have reached the rock, in some places over 90 feet down. Then workmen go to the bottom and with hammer and chisel cut away the base of the column and the rock until the one sits securely on the other.

When this is completed, the holes are filled up with concrete, and after the requisite number of these "columns" have been sunk at specified intervals, the spaces between them are filled in with more concrete, the top surface is made even, and the foundation is ready for the building of the solid granite wall.

Probably more granite will be used at these Keyham works than in any previous undertaking. Sir John Jackson, the contractor for the work, is bringing from Cornwall and Norway over 3,000,000 cubic feet. Some idea of the quantity of concrete required in carrying out this "dockisation" scheme may be formed from the fact that at one time there are stored on the site from 13,000 to 16,000 tons of cement for its manufacture, that 200 tons are used a day, and that six mixing machines, each capable of turning

ENLARGED VIEW OF THE STOTHERT & PITT GRAB OPPOSITE

THE TWO CABLEWAYS BRANCH OFF FROM ONE HEAD TOWER. GANGS OF MEN ARE EMPLOYED UNDER EACH CABLEWAY TO FILL THE SKIPS, WHICH ARE THEN LIFTED, RUN ALONG THE CABLE, AND DUMPED INTO THE CHUTES. INSTALLED BY THE TEMPERLEY TRANSPORTER CO., LONDON

out from 230 to 240 tons of concrete a day, are continually at work.

The execution of this contract has entailed the purchase of an immense plant. On the ground there are no fewer than 180 boilers, besides nearly 20 oil or gas engines. Millions of cubic feet of timber have been used for temporary stagings over the works, for wharves, and for the great towers from which an ingenious cableway works for the quick transport of the mud as it is loaded into trucks by workmen with shovels.

At first the ground was cleared by several steam "scoops," but that tool proved impracticable after a time, and now the elevated cableway is at work. Near the water-side is a high tower from which run two cables of wire, 8 inches in circumference, to two towers inland, which move on railways so as to bring the cable directly over the two armies of men at work on different parts of the area. As they fill trucks with the mud, a signal is made, and in an instant grapplers run along the cableway high over their heads, descend, pick up the truck and carry it to the great tower at the water's edge, where the contents are shot down into a hopper which steams away to sea and dumps it down at least four miles beyond Plymouth Breakwater. Sir John Jackson has at these works twelve hoppers, called "dumb hoppers," because they cannot propel themselves. Each of these ungainly vessels has a capacity of from 1000 to 1250 tons.

In addition, use is found for three steam hoppers, nine steam tugs and a number of small barges. Over 30 miles of double-track railway have been laid over the wharves and the site of the docks and basins, and thirty locomotives are continually bustling to and fro. The contract has necessitated the enlistment of the services of all kinds of workmen besides those engaged on the site. One big foundry is capable of turning out forty tons of castings a day, the smithy has twelve fires always blazing, making and repairing machinery, and in one workshop may be seen men engaged in putting together and repairing locomotives and other machinery, while nearby is a shed where dynamos

ONE OF THE 10-TON DERRICK CRANES MADE AND ERECTED AT KEYHAM

THE HEAD TOWER OF THE CABLEWAYS AT BETHAM. THIS TOWER IS COMMON TO BOTH CABLEWAYS. THE CHUTES ALSO ARE SHOWN DOWN WHICH THE SPOIL IS DUMPED INTO THE BARGES

ONE OF THE STONE BREAKERS FURNISHED BY MESSRS. W. H. BAXTER, LTD., LEEDS

are at work supplying motive power and light for the offices where a large clerical staff is engaged, and for the workmen who are kept busy at night.

There are few more weird sights than the works at Keyham late at night when battalions of men are seen working their hardest under the great electric arc lights. All the men seem to labour with a will, and one would think they were paid by the piece instead of by the day; but there is no piece work whatever at Keyham. There is, however, some system of bonus by which many of the men, by good work, are able to substantially increase their ordinary daily pay.

In other ways the welfare of the men is studied. When the work began it was discovered that, owing to local conditions, the living accommodation was quite inadequate. Sir John Jackson cast round for some remedy, for it stood to reason that they would not get the best class of workmen unless they could offer them a prospect of obtaining decent homes. At last, outside the borough of Devonport, and, therefore, not liable to the high rates of that town, they found a piece of land adjacent to the

PILING FOR THE DEEP TRENCHES

A VIEW OF THE STAGING FOR THE RIVER WALL

DRIVING CAST IRON PILES

works. This was purchased and cleared, and on this site they have put up 200 neat little houses,—in fact, they have created a small town of their own, besides stimulating the efforts of the speculative builder. When the contract at Keyham is completed it seems likely that the firm will have to enter a new branch of business, that of house agents and timber dealers, in order that they may dispose of their houses and millions of feet of lumber.

When this great task is finished, Devonport will be the best equipped dockyard in the world. At present it has no dock in which, in case of emergency, it could place the *Powerful* or the *Terrible* or either of the monster cruisers of the *Drake* class. As soon as the new works are completed there will be docks more than sufficiently large to take four of these swift leviathans, and seven other docks in the old dockyard to accommodate battleships and cruisers of less length. Then, indeed, Devonport will be in a proud position, and the whole British Empire will have cause for congratulation at the creation of a base so near the probable scene of battle and so splendidly fitted to shelter and repair disabled ships.

One side of the River Hamoaze is lined with government establishments of one kind and another for a matter of four

ONE OF THE CRANES SUPPLIED BY MESSRS. JOSEPH BOOTH & BROS., LTD., RODLEY, LEEDS

miles, and the docks and basins and ships and stores represent probably not less than one hundred millions sterling. It is recognised that an enemy might attempt to raid a harbour containing so much of value for warlike purposes. Consequently the government have been busy developing means of defence, and special attention has been given to protection against torpedo attack, which would be attempted under cover of darkness. On the cliffs overlooking the entrance to Plymouth Sound big guns have been mounted, two of them of 9.2-inch calibre. Nearer in are other guns,—on the breakwater that lies across the Sound, on the foreshore on either side, on Drake's Island that squats under Plymouth's famous Hoe, in the Citadel which rises at one end of the Hoe, and at the point where the Sound leads into the River Hamoaze, Devonport's harbour.

At the entrance to this great inner anchorage, at its narrowest point, a boom would stretch in time of war, supported by gunboats. It would be arranged so as to allow friendly vessels to go in and out in the daytime, but would bar all entrance at night, except under exceptional circumstances, as, for instance, when a British man-of-war came into the harbour after dark in a seriously damaged condition. All these guns are

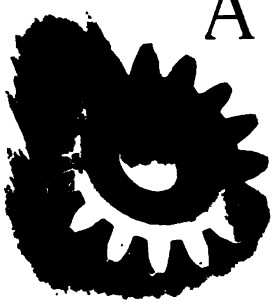
supported by a number of searchlights, so placed as to throw beams of light across all the means of approach, and there are also mine fields of deadly suggestion. In fact, experiment has shown that Plymouth has been rendered impregnable against attack, and therein is great cause for congratulation.

The engineer-in-chief of the Keyham extension works is Sir Henry Pilkington, K. C. B., who is also engineer-in-chief of the other great Admiralty works now being carried out in different parts of the world, including Simon's Bay (of which Sir John Jackson is also the contractor), Gibraltar, Dover, Malta, Hong Kong and others, in all probably representing an expenditure of £20,000,000. C. Colson, Esq., C. B., is the assistant engineer-in-chief for the Admiralty, and the Admiralty superintending civil engineer in charge of the works at Keyham is Mr. Whately Eliot, M. I. C. E., who has had large experience in similar works. Mr. G. H. Scott, M. I. C. E., one of the directors of Sir John Jackson, Limited, has had full charge of the works for the contractors from the commencement, and is assisted by a large staff, both engineering and clerical.

CUT GEARING

AND SOME AMERICAN MACHINERY FOR ITS MANUFACTURE

By Oscar J. Beale



AMONG the details of machine making cut gearing occupies a prominent place. Gearing is assertive. If anything be wrong with a quick running pair of gears they are likely to make a big noise about it. The noise is easily enough sound, but the cause and its removal have long been puzzles. Much thought has been devoted to the devising of means to avoid disagreeable sounds, and in bad eminence, few sounds are equal to the noise of gears.

As a mechanical movement the purpose of a pair of gears is easily understood,—that one toothed member drive another in accordance with some law, which is usually a constant velocity ratio. The construction of a pair of gears answering the mechanical requirements is not accompanied with any special uncertainties, but the construction of "noiseless" gears is one of the most uncertain of all the problems that mechanics ever have to solve; indeed, almost as much time is spent in the attempt to produce "quiet" gears as is spent in studying the principles of gearing.

The Brown & Sharpe Manufacturing Company, in a book entitled "Practical Treatise on Gearing," say:—"Not many questions can be asked us to which we can give a less definite answer than to the question why gears are noisy."

The difference between noisy gears and quiet gears is often so slight that an expert cannot decide, by mere inspection, to which class a given pair of gears belongs. Both kinds are not infrequently produced in the same lot, apparently under the same conditions. This is disquieting, and may lead to misunderstandings. The inspector has heard so many explanations as to how the bad work came about that he has become skeptical, and when he is told that the noisy gears were turned, cut, and fitted to place exactly like the quiet gears, his belief in narrative statements receives another shock.

A pair of gears about an inch in diameter, at 10,000 to 15,000 revolutions per minute, will sometimes set up a distressing noise, approaching the shriek of a small steam whistle, which may come from motion of the air and not from faults of construction. And so a constructor of gears has a peculiar anxiety,—he is not at all concerned as to the geometrical movements of his gearing so long as it will keep quiet. He has various devices, other than the correct shaping of the teeth, with which he hopes to avoid disagreeable sounds; if he has light power to transmit, he may choose a fine pitch for the teeth; he may make his gears of brass, sometimes of rawhide, and again of compressed paper.

One of the details of construction that may cause noise is that the depth of the tooth spaces is not right. In this respect gears are oftener cut too deep than not deep enough, and it is worse to have the driver too deep than the driven gear. Another cause of noise may be that the cutting is not central. This may be shown by gears being noisy in one direction and quiet when running in the other direction. Again, the centre distance may not be right; if

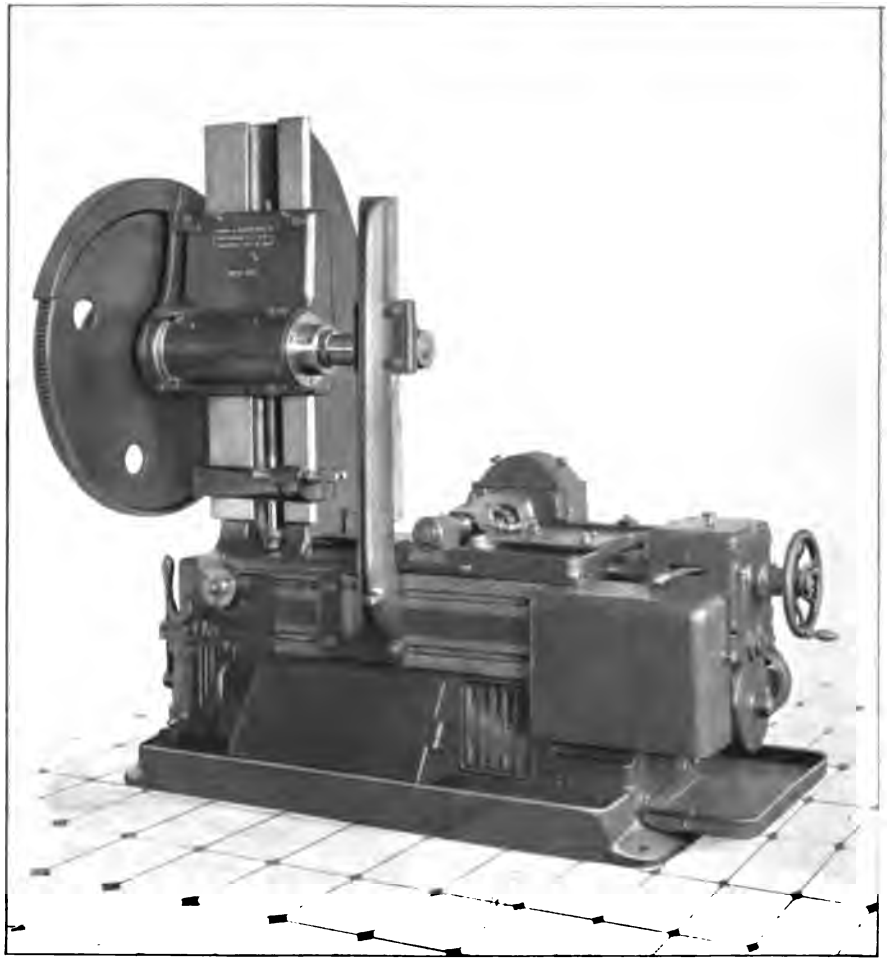


FIG. I.—AN AUTOMATIC GEAR CUTTER MADE BY THE BROWN & SHARPE MFG. CO., PROVIDENCE, R. I.

meshing too deep, the outer corners of the teeth of one gear may strike hard against the roots of the teeth of the other gear. Still another reason for noise may be found in the fact that the frame carrying the gear shafts may be of such form and size as to give off sound vibrations.

Theoretically, the action of bevel gears is smoother than that of ordinary spur gears, because the teeth of bevel gears remain longer in contact than those of spur gears. Bevel gears, however, must be in correct position endwise, as well as sidewise, and oftentimes a bevel gear overhangs its shaft bearing, making it a little more liable to wear out of position, which is a reason why some mechanics avoid bevel gears when they can. The teeth of internal gears remain in contact longer than those of any other class of gears.

The action between the teeth of two spur gears is a combination of rolling and of sliding. Between gears of one hundred teeth or more the sliding does not wear the teeth very fast, while a low-numbered pinion may be short-lived.

In screw gears which connect shafts that are not parallel the driver acts somewhat like a screw, and the sliding

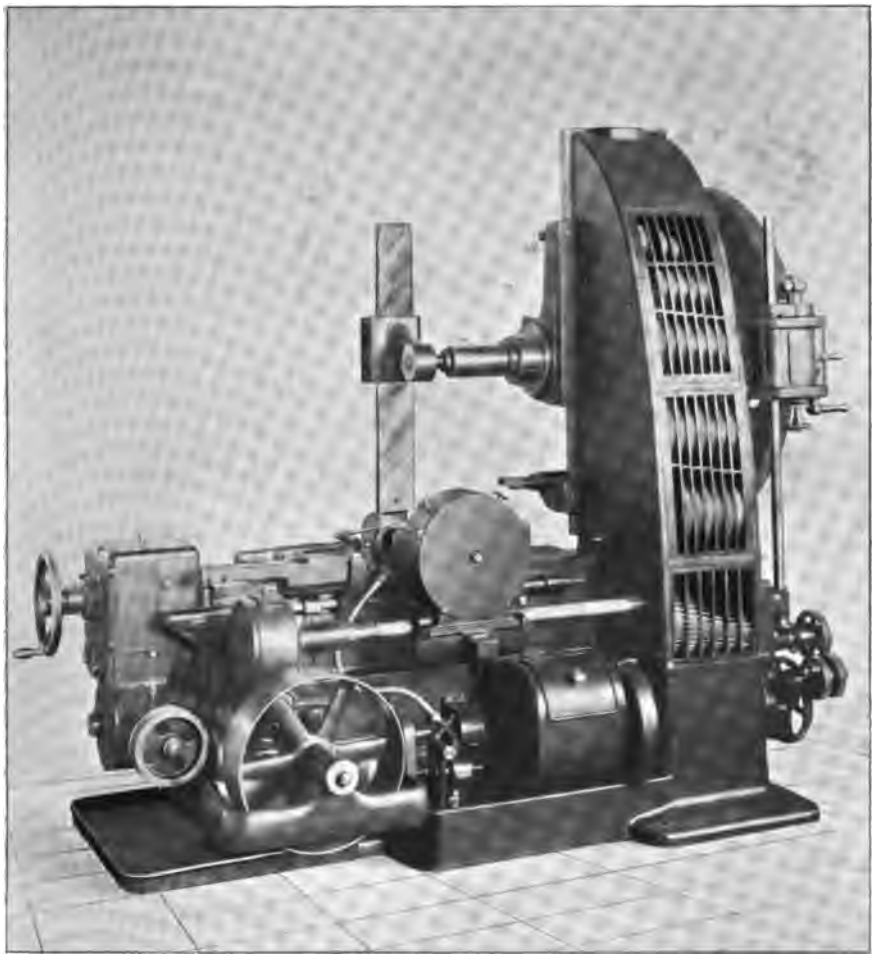


FIG. 2.—ANOTHER VIEW OF THE MACHINE SHOWN IN FIG. 1

action is much greater than the rolling. Screw gears include the two classes of worm gears and of spiral screw gears. A worm gear, or wheel, has teeth curved to follow the form of the worm thread, which increases the number of bearing points and lengthens somewhat the lifetime of a worm and wheel. In spiral screw gears the teeth do not conform to one another, but bear only in points, and in consequence these gears are the shortest lived of all gears.

If screw gears are to do heavy duty, at least one member must run in oil. At their best, spiral gears are uncomfortably near the border line of destruction. If a tooth of one gear comes in contact with a particular tooth in the other, at every revolution of one gear a slight roughing up between two teeth that come in contact often keeps increasing until they, and several of their neighbours in a less degree, are reduced to powder. This may be avoided with a "hunting tooth," which means that every tooth in one member of a pair of gears, after touching a tooth in the other gear, "hunts" or comes in contact with every tooth in the other gear before touching the same tooth again. This is accomplished by letting the numbers of teeth in the two gears have

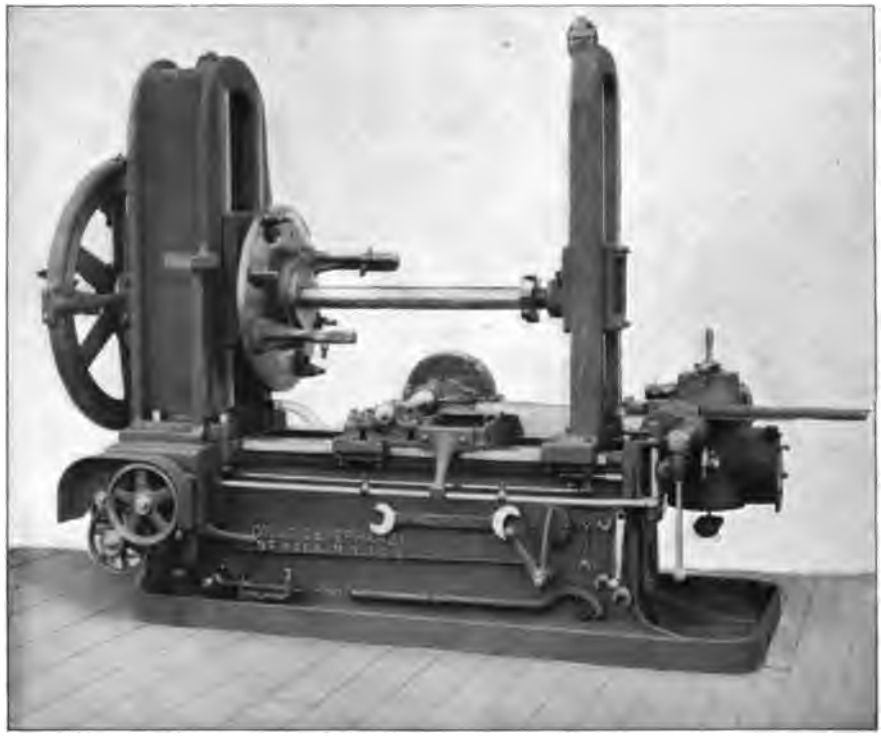


FIG. 3.—AN AUTOMATIC SPUR GEAR CUTTER MADE BY MESSRS. GOULD & EBERHARDT, NEWARK, N. J.

no common factors. If the larger member have twice as many teeth as the smaller, the larger may have two groups of worn teeth, while the smaller has only one, and so on.

After all that has here been said in criticism of spiral screw gears, the writer is free to admit that many are in use which have been running for years and have never given the slightest trouble. Perhaps there is no mechanical subject upon which men more easily become opinionated than that of gearing in general; and the writer has known more surprises to come through spiral gears than through all other kinds.

George B. Grant says:—"The combination known as a worm gear and worm is much used for obtaining slow and powerful motions. It is also much used for wasting power and wearing itself out, for its friction is very great and consumes from one quarter to two-thirds of the power received."

In a power-transmitting device the ratio of the power given off to the power received is called the efficiency of the device. If a pair of gears consume one-quarter of the power received, their efficiency is the remaining 75 per cent. Efficiency is merely a ratio; a pair of gears may have very little work to do and yet consume a large part of the power received,—that is, the efficiency may be low, even though the work be light.

In many combinations the efficiency does not count for much, the important points being quietness and durability; but in cases where power is paid for according to a meter, the efficiency of gearing is a matter of importance. Many electric elevators are cases of this kind, and it is a notable fact that in these worm gearing is often employed. Some makers of elevators prefer the Hindley worm. This is a worm curved to conform as nearly as may be to the worm wheel, which also is curved to conform to the worm. Whether the

conformation of the worm to the wheel, however, really adds much to the wearing contact has been questioned.

While mention has been made of some of the troubles with gearing, the subject has also its brighter side; not all the points have to do with noise and wear and pulverisation. There are some intricate and beautiful problems in gearing the solution of which forms a fascinating study. Mathematical experts have in various ways sought to lessen the work of delineators and constructors of gearing. Professor Willis invented his "odontograph" or "tooth-delineator," and computed tables for its use to delineate tooth outlines with arcs of circles approximating the exact curves. Professor Robinson has invented a templet odontograph, a portion of the templet outline being used to delineate the tooth outline. Professor Klein has computed tables to determine with coördinates a number of exact points in a tooth-outline, the points being so near together as to be a close guide in completing the outline. Professor Willis' invention was used for many years, but nowadays there is a tendency, in cut gearing, to avoid every approximation.

Several machines have been invented to describe or to cut gear tooth outlines by evolution. We can say of such a machine that it represents a group of geometrical laws crystallised into wheels and strong arms which afterward go on reproducing outlines of teeth in correct form.

In accordance with the geometry of gearing, there are numberless curves for the tooth outlines which will satisfy the conditions of the problem that one toothed member drive another in a given velocity ratio. But of all the curves that can be chosen there are only two in common use, the epicycloidal and the involute. Teeth of the epicycloidal outline are usually called double-curved teeth, and the involute are called single-curved. It is a curious fact that while the epicycloidal system is the easier to understand, and is usually the first to be taken up in a course of study in gearing, in practical use it is being

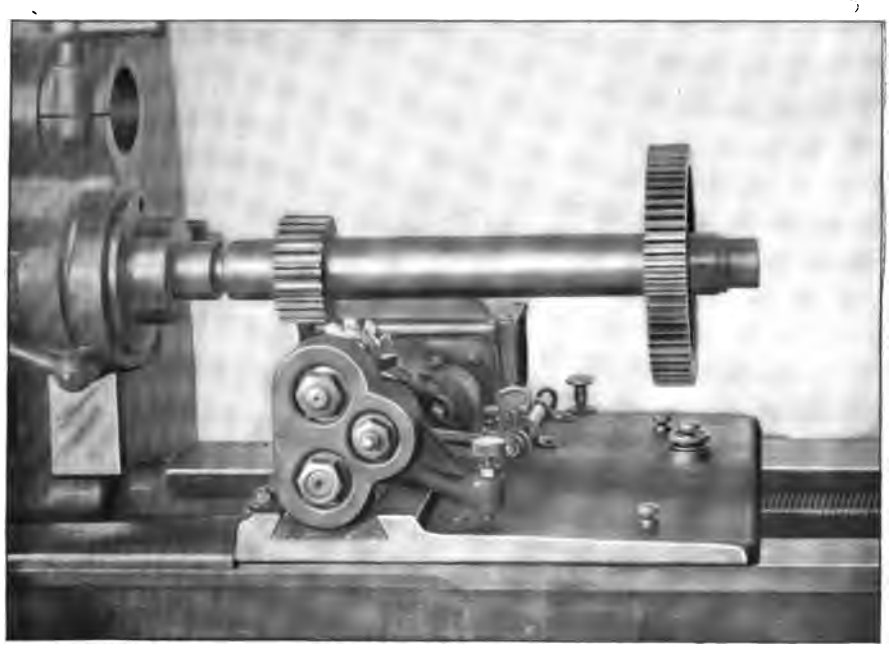


FIG. 4.—AN ATTACHMENT FOR CUTTING QUILL GEARS

FIG. 5.—AN INTERNAL GEAR CUTTING ATTACHMENT

more and more superseded by the involute.

In order to obtain a good combination of epicycloidal gears the details of construction must be well nigh exact, while a fairly good combination of involute gears may be obtained with ordinary care. The difficulties of construction have had much to do with the tendency to abandon the use of epicycloidal teeth, but even at their best they have not been found, in practice, to be at all superior to the involute form.

In connection with this it is interesting to note the curious fact that after a machine for making gears has been carefully constructed in accordance with the principles of gearing, and when, according to the laws of geometry, it must delineate correct tooth forms, the careful mechanic will not accept the work of the machine until he has tested it by methods that might be called "hand and eye operations." It is well known that some pieces have to be corrected after being machined, familiar examples being the flat sliding parts of almost any mechanism, which must be scraped after being planed. After testing the machine, its work can be accepted as correct enough, especially if the machine is employed only to describe the tooth outlines. A good test of the machine rests upon the fact that, in describing tooth flanks, when the describing circle is half the diameter of the pitch circle the flanks are straight lines and radial. Now by setting up the machine for radial flanks, the work of the machine can be tested with a straight edge.

In shaping the teeth it is well to have the outer corners rounded or cut away from one to three one-thousandths of an inch under the exact tooth outline in order to avoid the harsh action of the tooth flanks of one gear upon the outer corners of the teeth of the other gear. If the teeth are of exact geometrical outline, an outer tooth-corner is under full working pressure action as soon as it touches the engaging tooth. This amounts to a blow, and makes the action rough and noisy. The action between the teeth as they approach the line of centres is called "approaching action," and as they recede, "receding action."

The approaching action is so objectionable to clock makers that they avoid it altogether by having the tooth addenda of the driven gear entirely inside the exact outline, so that only the faces

of the driving teeth ever come in contact with the teeth of the driven gear, and this contact is entirely upon the flanks of the driven teeth, the action being wholly receding. In ordinary gearing it is not practicable to wholly avoid the approaching action.

Machines for cutting the teeth of wheels can be broadly divided into three classes:—

1.—Machines that use a cutter, formed to the required space between two teeth, the outline of the space cut being a copy of the cutter in reverse.

2.—Profiling machines, in which the movements of the cutter or of the tool are controlled with a former, so as to shape a tooth, the former being copied and not the cutter.

3.—Generating machines, in which the tooth outlines do not depend upon formers, and the outlines cut are not copies of the cutting tools.

1.—Any machine illustrated in this article that has the cutter-spindle at right angles to the index or work-spindle is of the first-named class, in which the cutter shapes the teeth directly. Among machines of this class are different types made by the Brown & Sharpe Manufacturing Company, of Providence, R. I. (Figs. 1 and 2), and by Messrs. Gould & Eberhardt, of Newark, N. J. (Fig. 3), in which the index spindle, which carries the gear blank, is horizontal and is adjusted vertically to accommodate the diameter of a blank and the depth of cut. The cutter spindle is below the work spindle, the cutting of the teeth being at the under side of the gear blank. An attachment to a Brown & Sharpe machine is shown in Fig. 4 for cutting quill gears, and another attachment in Fig. 5 for internal gears. Both these machines are automatic. The cutter spindle is carried forward and back with the cutter slide, the cutter being fed through the tooth space as it is being cut.

Another type of this class is an automatic machine (Fig. 6) made by the

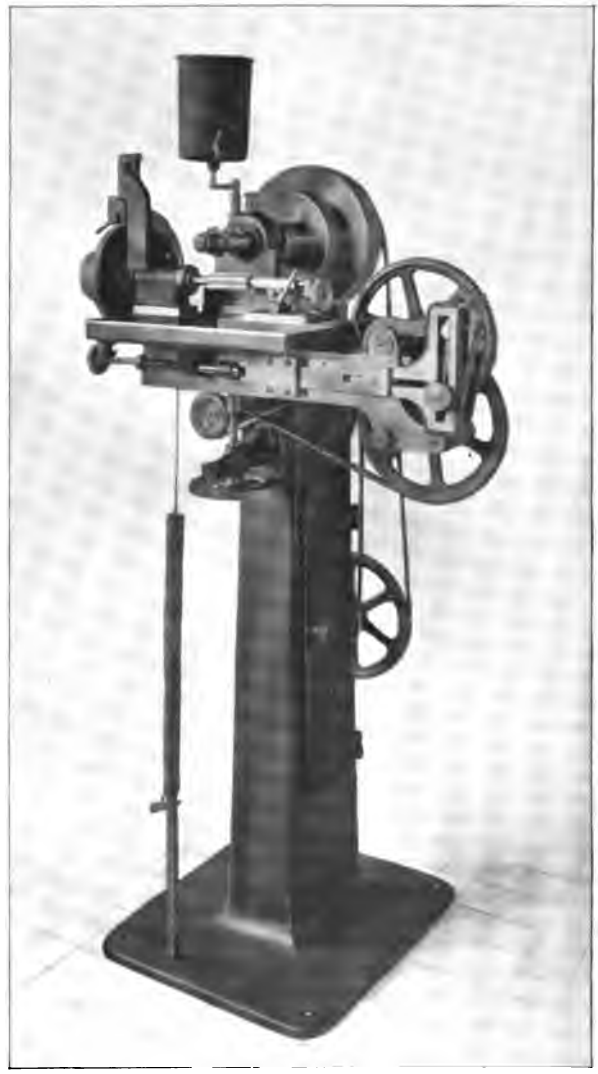


FIG. 6.—GEAR CUTTER MADE BY THE DWIGHT SLATE MACHINE COMPANY, HARTFORD, CONN.

Dwight Slate Machine Company, of Hartford, Conn., in which the index spindle is also adjusted vertically, but the cutter spindle is above the index spindle, the cutting of the teeth being at the upper side of the blank. In this machine there is no cutter slide and the cutter is not fed through a tooth space, but the index spindle is mounted upon a table which is moved with a cam, the shaft the blank is fed forward and returned and the blank is indexed.

When the movements in a machine can be obtained with cams or cranks the machine is somewhat less expensive than when the movements are so long as to require clutching and unclutching devices or other reversing devices. A good illustration of this principle is seen in the difference between a crank planer

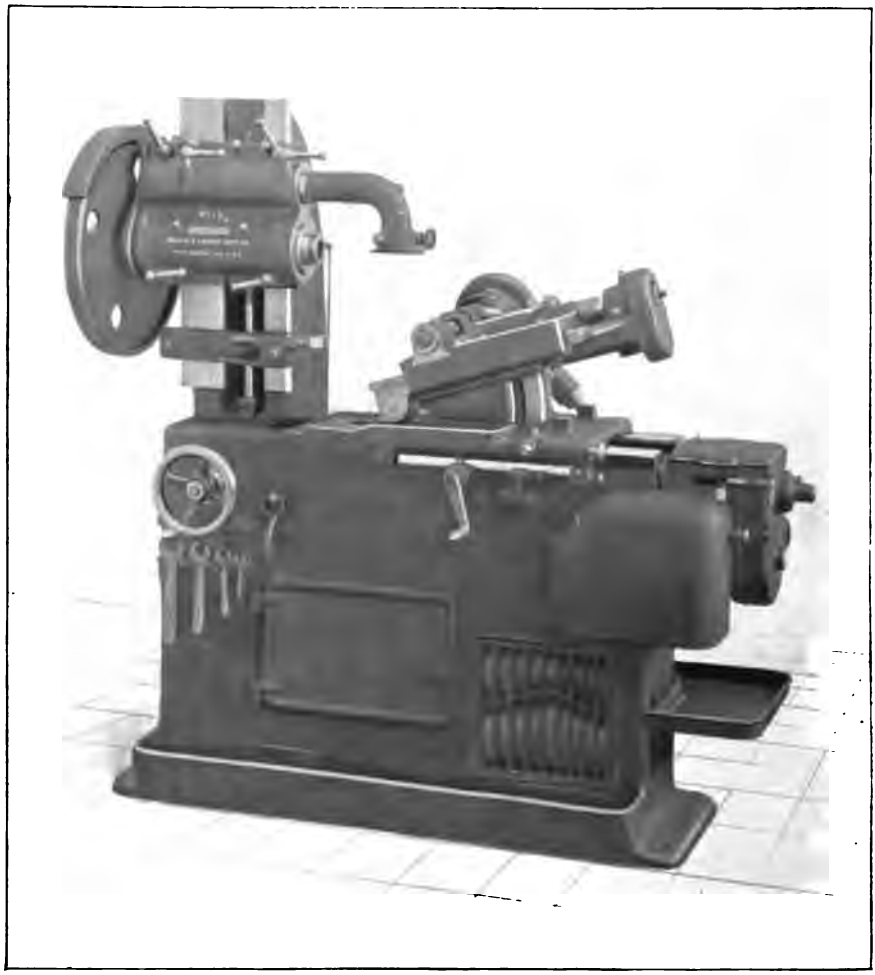


FIG. 7.—AN AUTOMATIC BEVEL GEAR CUTTER MADE BY THE BROWN & SHARPE MFG. COMPANY, PROVIDENCE, R. I.

blank being fed past the cutter, which is available in machines for cutting gears of not more than 3 or 4 inches width of face. During one revolution of the cam and a rack planer. In a crank planer the reversing is done by the mere rotation of the crank, while a rack-driven planer requires special reversing de-

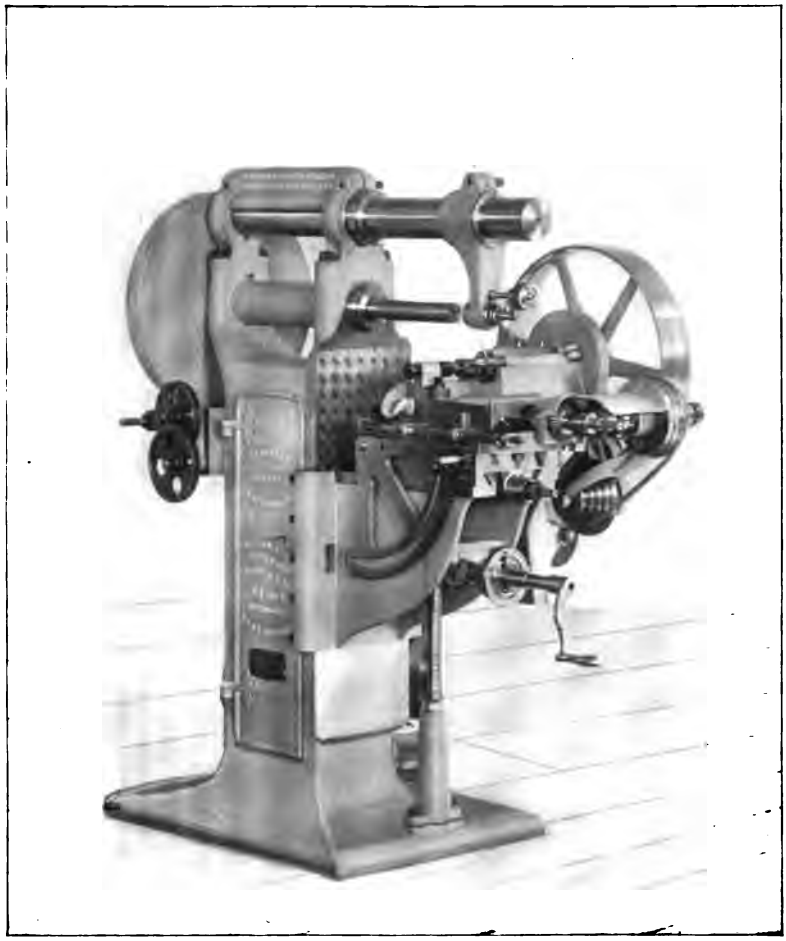


FIG. 8.—AN AUTOMATIC BEVEL GEAR CUTTING MACHINE MADE BY THE BECKER-BRAINARD MILLING MACHINE CO., HYDE PARK, MASS., U. S. A.

vices. Some mechanics classify an open and a crossed belt as the simplest form of a pair of reversing friction clutches.

An automatic bevel gear cutting machine by the Brown & Sharpe Manufacturing Company, of Providence (Fig. 7), and another by the Becker-Brainard Milling Machine Company, of Hyde Park, Mass. (Fig. 8), are types of the class first named, in which the cutter forms the teeth direct. In both these machines the index spindle is horizontal. Each machine has a cutter slide which can be inclined to the cutting angle of a bevel gear. In the Brown & Sharpe machine the index spindle is adjusted vertically. In the Becker-Brainard machine the cutter spindle is carried upon a slide mounted upon a carriage knee which is adjusted vertically. In its adjustments and in its general outline this machine resembles a column milling machine. In cutting spur gears the depth of cut depends directly upon the distance between the index spindle and the cutter spindle; in bevel gears the depth of cut can be varied by moving the cutter carriage parallel to the index spindle which changes the inclined cutter slide in relation to the gear blank.

Two other types of this class are represented in the spur and bevel gear cut-

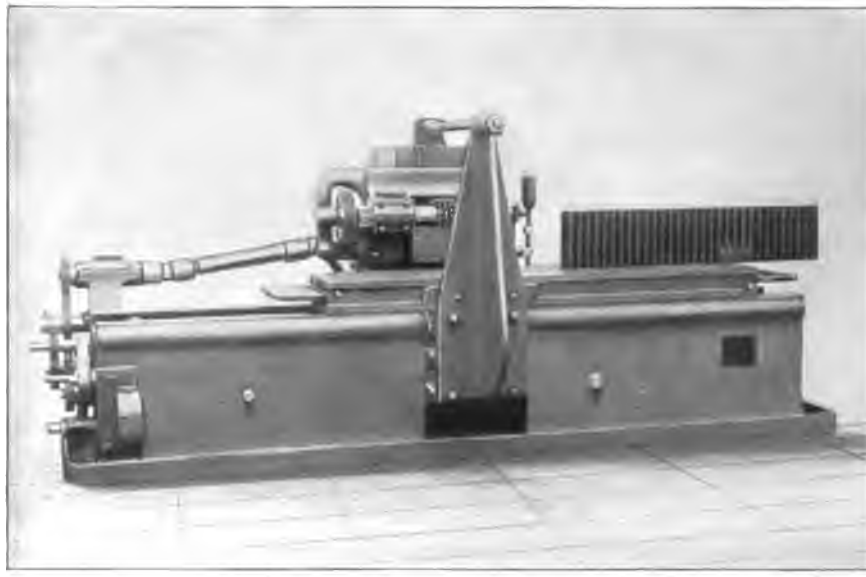


FIG. 9.—A RACK CUTTING MACHINE BUILT BY MESSRS GOULD & EBERHARDT, NEWARK, N. J.

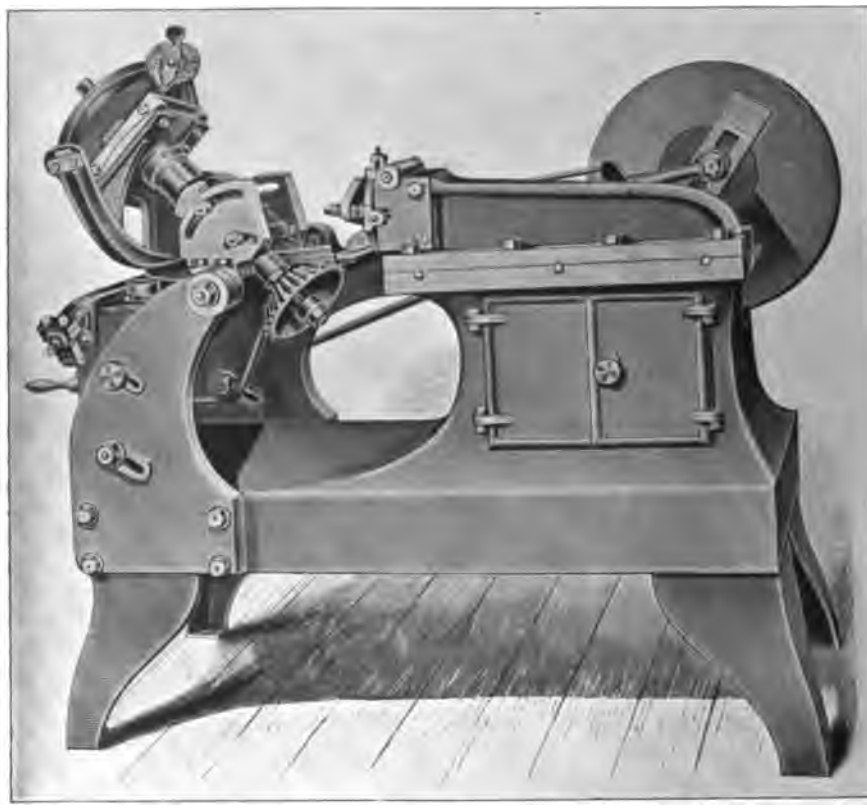


FIG. 10.—GEAR PLANER MADE BY HUGO BILGRAM, PHILADELPHIA, PA., U. S. A.

ting machine made by Messrs. William Sellers & Co., Inc., of Philadelphia, and in the spur and worm-wheel cutting machine of the Pratt & Whitney Company, of Hartford, Conn. (Fig. 13). In both these machines the index spindle is horizontal and is adjustable horizontally, the cutter spindle being perpendicular and the cutting of the teeth being at one side of the blank. The Sellers machine is automatic.

The last gear cutting machine here shown belonging to the class that forms the tooth outlines directly with the cutter is made by the Newton Machine Tool Works, of Philadelphia (Fig. 11). In this machine the index spindle is upright, the cutter spindle being horizontal. The index spindle runs in stationary bearings in the machine bed and the cutter head is adjustable. In addition to the usual power cutter feed, the machine is also indexed by power.

In a rack-cutting machine there are difficulties in driving the cutter spindle that do not occur in driving the spindle of a gear-cutting machine. A rack being straight, the cutter spindle and its boxes must clear the face of the rack when the cutter is at the full depth. Again, either the driving member on the cutter spindle must be small enough to clear the face of the rack or the cutter spindle must be long enough to let the driving member clear the end of the rack.

The Gould & Eberhardt rack-cutting machine (Fig. 9) has a cutter spindle driving member that is smaller than the cutter. The action of driving a cutter with the smaller member is easier, as the ratio of the diameter of the driving

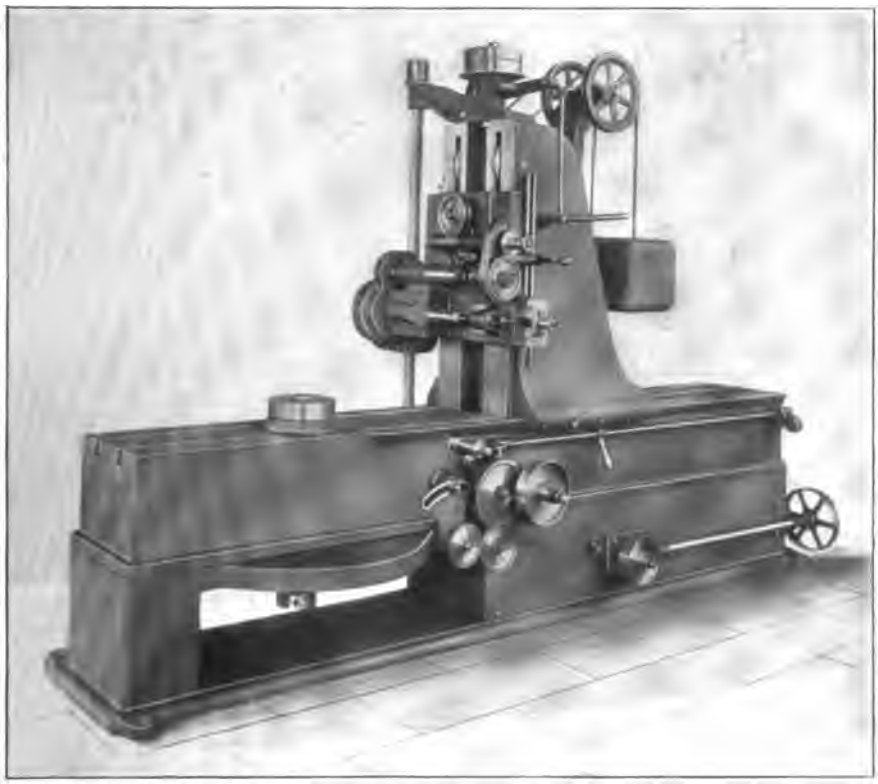


FIG. 11.—SPUR GEAR CUTTER MADE BY THE NEWTON MACHINE TOOL WORKS, PHILADELPHIA. THIS MACHINE WILL CUT GEARS UP TO 10 FEET IN DIAMETER

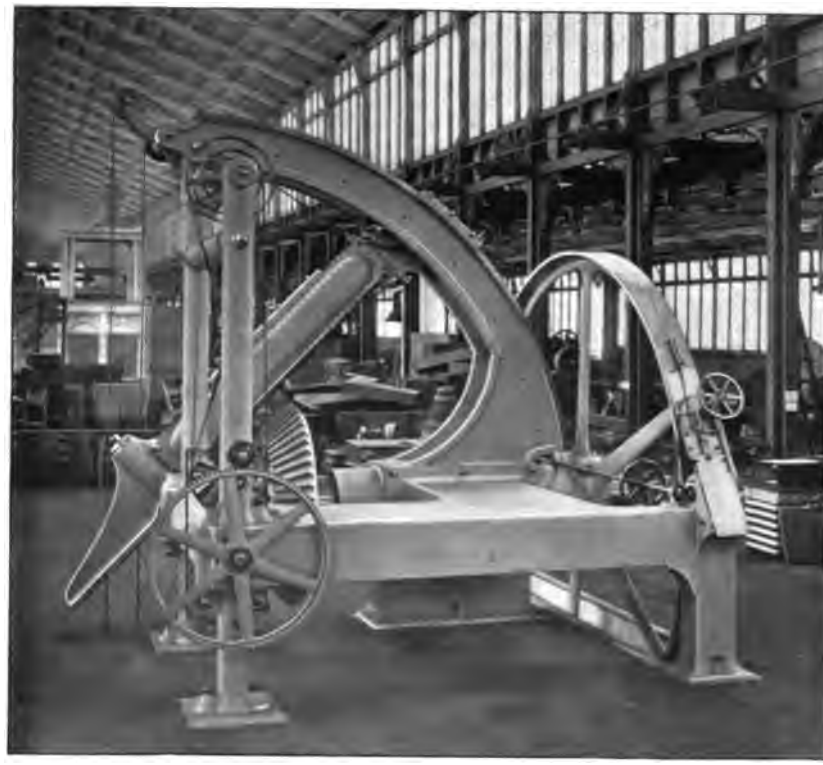


FIG. 12.—THE CORLISS BEVEL GEAR PLANER

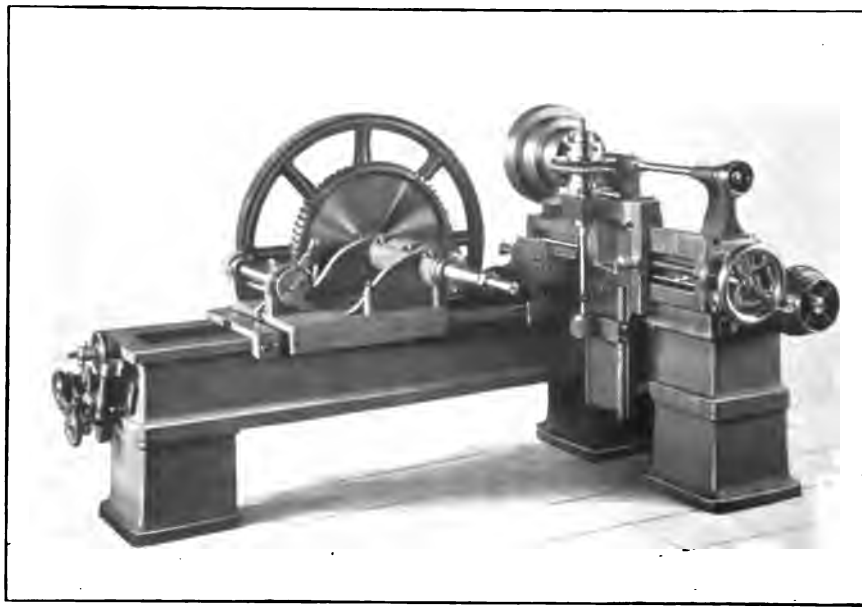


FIG. 13.—A SPUR AND WORM WHEEL CUTTING MACHINE BUILT BY THE PRATT & WHITNEY COMPANY, HARTFORD, CONN.

member to the diameter of the cutter is greater. For example, if the driving member is seven-eighths the diameter of the cutter, the action is easier than if the ratio were only one-half. If the ratio is as small as one-half, some of the parts in the driving mechanism are likely to rapidly destroy one another.

2.—The principle of profiling, by which the shaping of the teeth is controlled with a templet or former, has been employed in the cutting of bevel gears. One type of this class of machines, which cuts with a reciprocating tool, is called a bevel-gear planer. The tool cuts along straight lines that converge at the apex of the gear, or at the common point of the axes of the gear being cut and the mate or engaging gear. The tool slide moves upon an arm having a universal joint whose centre is at the apex. Such a machine is, in a sense, a radial bar pantograph machine, the free end of the bar being controlled by the edge of a templet as the bar is fed along. The templet represents the outline of one side of a tooth, enlarged in the ratio of the length of the bar to the apex distance of the gear to be cut.

George H. Corliss took out a United States patent for a bevel-gear planer in 1849, but Mr. George B. Grant says that a bevel-gear planer was patented in France by Glavet in 1829, twenty years before Corliss, who was the first to introduce it into America. Fig. 12 is an illustration of a Corliss bevel gear planer. It is now set to cut a miter gear. The radial cutter slide carrying bar is seen inclined to an angle of about 45 degrees.

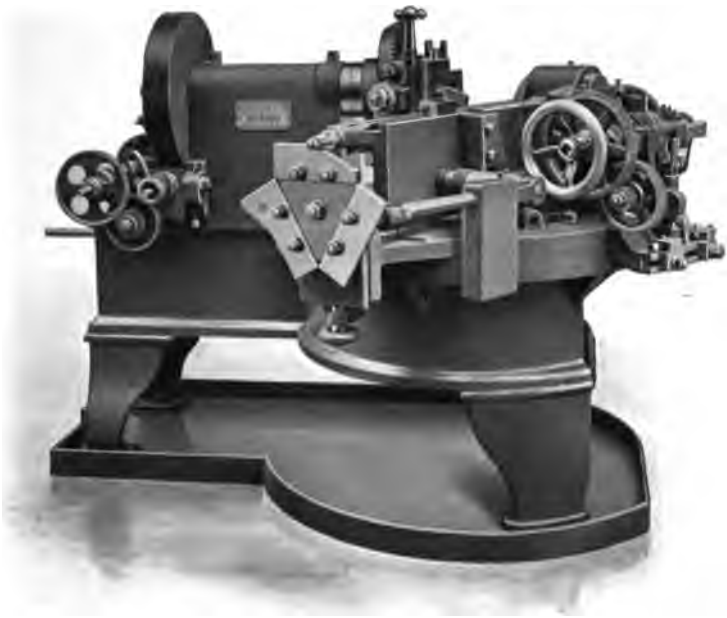


FIG. 14.—A BEVEL GEAR PLANER BUILT BY THE GLEASON TOOL COMPANY, ROCHESTER, N. Y.

Fig. 14 shows an automatic bevel-gear planer made by the Gleason Tool Company, of Rochester, N. Y. Three templets are clearly shown, fastened to a triangular holder which can be set to bring any templet uppermost so as to control the radial bar by means of a small roller which is seen resting upon the upper templet. The lower right hand templet is straight, and is used to

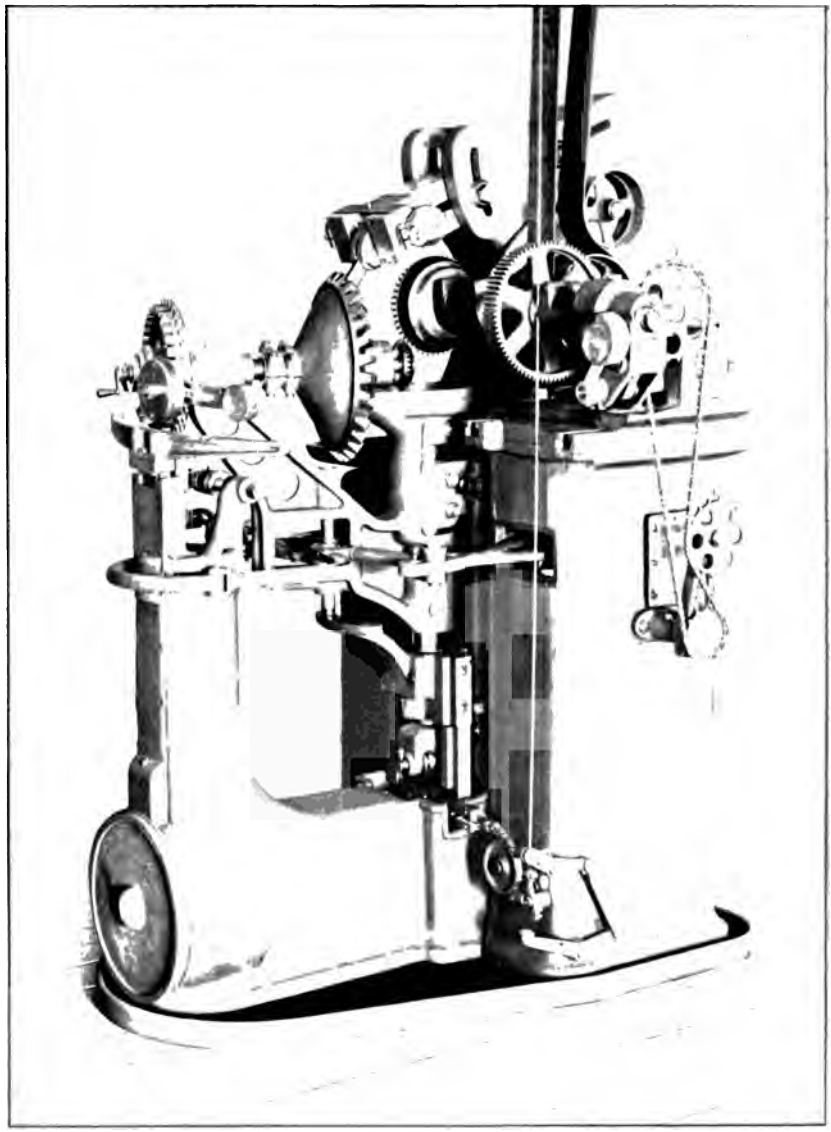


FIG. 15.—A BEVEL GEAR GENERATOR INVENTED BY C. D. RICE, SUPERINTENDENT OF THE UNDERWOOD TYPEWRITER MFG. COMPANY, HARTFORD, CONN.

rough out tooth spaces. A remarkable type of the profiling class of machines is seen in the Rice bevel-gear cutter (Fig. 15). Instead of the former being stationary, it is moved, and the rubber remains stationary. The former is in reality a gear, say, five times as large as the gear to be cut, both being fastened to the same arbour and having a common apex. This arbour is carried in a frame that swings about a vertical axis, passing through the apex of the former gear and the gear to be cut.

The teeth of a gear are cut with a plane rotary cutter. The rubber is also

plane, the bearing side of the rubber and the cutting side of the cutter being upon a straight line that passes through the apex of the gear. The former is swung about the rubber, which also swings the gear about the cutter. The latter cuts in straight lines converging at the apex. This method of ploys a tool having as small a point as is consistent with strength and with the lifetime of the cutting edge, the point of the tool being actually moved in a path corresponding to the tooth outline with mechanism other than a former. Not many machines of this type have been brought out, and their practical

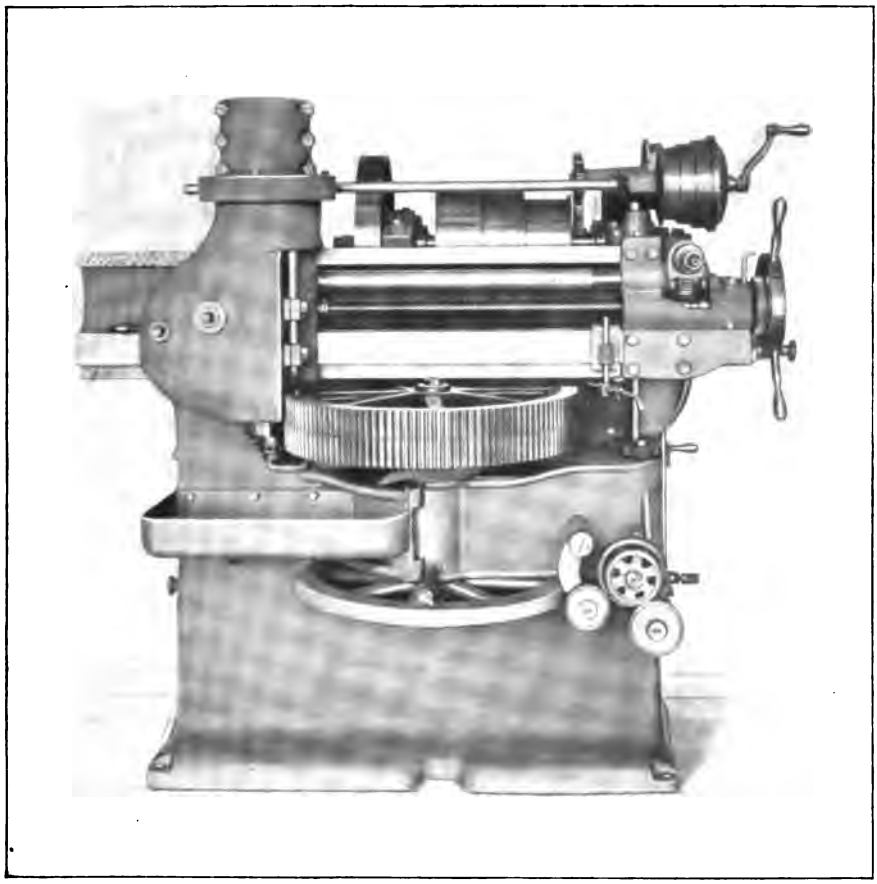


FIG. 16.—GEAR SHAPER MADE BY THE FELLOWS GEAR SHAPER COMPANY, SPRINGFIELD, VT.

filing is available when no part of the outline of a cross section of a gear tooth is concave, and, for such teeth, it is mathematically exact.

3.—There are two types of gear-tooth generating machine in which the tooth outlines do not depend upon formers and the outlines are not copies of the cutting tools. One of these types em- use has not become familiar to mechanics generally.

The other type of generating machine rests upon what is technically known as the conjugating principle. If one gear forms or cuts the teeth in another gear while both are rotating in correct relation to each other the two gears will run correctly together. If the forming gear

is interchangeable with other interchangeable gears of the same pitch, the formed gear will also be interchangeable. While the tooth outlines in the formed gear are not copies of the forming gear teeth or of the cutting tool, yet the outlines depend in part upon the shape of the forming tool.

The Fellows gear shaper (Fig. 16) is a conjugating machine. A hardened steel gear reciprocates across the face of the gear blank to be cut, both being rotated in correct relation to each other. The hard gear cuts in various positions, which is equivalent to forming teeth as by the conjugating principle.

The bevel-gear cutting machine, or gear planer, made by Hugo Bilgram, of Philadelphia, is another example of the conjugating principle. It is shown in Fig. 10. The tool cuts on one side, which is equivalent to the forming of one side of a tooth with one side of a crown wheel tooth. The tool is adjusted so that the corner of the tool on one side will move directly toward the apex, and all the teeth are finished on one side. The tool is then adjusted so that the other corner will move toward the apex, and the teeth are finished on the other side.

While the tool reciprocates, the gear blank is moved so as to roll, geometrically, upon its pitch cone, about the apex, and against a nearly horizontal plane at the upper side of the cone.

BRITISH VIEWS OF AMERICAN WORKSHOPS

A BRITISH TRADES UNION VISIT TO THE UNITED STATES

By Alfred Mosely

By far the most interesting event that has ever taken place in international trades union circles has been the tour of inspection of several weeks, through some of the leading American industrial establishments, just completed by a delegation of twenty-three British trades union officials, who had been brought to the United States for this purpose by Mr. Alfred Mosely at his own expense.

They were to see for themselves all that was to be seen, in that time, under the exceptionally liberal facilities accorded for examination, of American workshops and workingmen's conditions and methods, and, on their return to Great Britain, to tell the several labour organisations which they represented what their experiences had been.

A brief forecast of what, in all likelihood, will be the general drift of their reports, though it represents really only the views of Mr. Mosely himself, is given in the following remarks made by him at one of the gatherings early last month of the annual convention at New York of the National Civic Federation,—an organisation whose aims and make-up were admirably presented in this magazine for February, 1902. To this some readers may find it worth while to refer at this time. Briefly put, however, the National Civic Federation is an association of thirty-six leading representatives of American labour, capital, and the general public, the object of which is to prevent strikes and lock-outs by bringing the contending parties together at a conference, to talk their differences out before matters have reached an acute stage.

Once a year this body holds a convention and its opportune meeting at the time of the return to New York of Mr. Mosely and his labour delegates, afforded to these men, before returning to Great Britain, the privilege of an additional American experience of unquestionable interest; at the same time their attendance at the meeting made available for the members of the Federation views and opinions from their British visitors which contributed materially to the value of the proceedings.

Mr. Mosely's work in providing for an educational trip of this kind for British workingmen promises, even at this early stage, to be of far-reaching benefit to international industrialism, that is, so far as Great Britain and the United

States are concerned, and it is to be hoped that the promise will materialise most substantially.—THE EDITOR.

I HAVE been requested to say a few words, because the gentlemen who have honoured me by accompanying me to the United States have aroused a great deal of attention everywhere, and it may perhaps be of interest to you to hear what they have seen and how I, from my standpoint, view the situation.

What led me to make this trip? It has been asked all over the country, and I will tell you. I am a colonial, English born, but I have spent the greater part of my life in the British colonies, principally South Africa. I was there interested in mining. We mined for years, in our diamond mines especially, with a number of different English engineers, but we made no progress. Diggers came and went, some held on by the skin of their teeth and others made a little money, but the great bulk failed. Companies were formed, and they, in turn, one after the other, had to close down, until an American engineer called Gardner Williams arrived upon the scene, and he was followed by a large number of others, and it is to the American engineer that we owe the success,—all the success,—of South Africa.

The mining propositions have been put on a sound basis in South Africa, not by the English engineer in the first place,—he may have learned afterward, —but primarily by the American. I was astonished by their methods, and I made up my mind it was necessary, as one who studies economics, to visit the country that had produced such men, that had been able to show us the way when we thought that we led the world. Five years ago I came to the United States and went through the country, and I became convinced that American methods, the American general mode of handling business propositions, was far ahead of our own in the old country. We who had led the van of the world for many years had become somewhat rusty. We were in the position of a man who had eaten a good dinner and had sat down to smoke a good cigar, away from the rest of the world. We know to-day that such a position is dangerous; it does not meet with progress. But it is the natural result of too much prosperity.

I went back to England five years ago with the information to my friends and to the public that I thought things were progressing in the United States at a speed that we ourselves did not realise, and I set about the work which, I am happy to say, we have brought, so far, to a successful issue. It was useless to invite the delegates of the trades unions to accompany me to America unless I had the sympathy of the American manufacturers and the people, and accordingly I came to the United States six months ago with letters of introduction to the most influential commercial and industrial gentlemen of the country, with a view of ascertaining whether such a delegation as I wished to bring would be acceptable to the American people, as a whole, and whether the manufacturers would be prepared to open their doors to us, to view what they had to show. It gives me great pleasure to say that upon that trip, as upon the present one we have been taking, I found the warm hand of welcome held out, the heartiest hand of welcome it was possible to imagine. Everyone was interested; everyone wished to help them all to study and learn what they had come to see.

It was an attitude, I must own, that astonishes me ; I am filled with admiration for a people who can be so broad as to extend the knowledge of themselves to others from another country. I went back to England and issued my invitations to the various trades unions representing the principal industries. The consequence was twenty-three gentlemen accepted, all but one of those I had asked, and they have accompanied me and have been busy for the past six weeks going over this great country. We have visited Schenectady, Niagara, Buffalo, Cleveland, Chicago, Dayton, Pittsburgh, Washington, Philadelphia, New York, and a number of other places,

largely in the East, Boston and all around the New England States, and I am sure that these gentlemen are now primed with a mass of information which they will take home to the old country, and which, I feel sure, can be productive only of good to British workmen and manufacturers.

There have been many points that have struck me, and I think have struck the delegates with equal force, as to the difference of conditions between the old country and the United States. One is the general adoption in the United States of piece-work, with the result that better wages are earned, I believe, here,—infinitely better wages than we pay on the other side.

Why is it that the workmen in America can earn so much better wages, and the manufacturer can make large profits, and can yet compete in the world's markets with his products? It is a very important question for the delegates to have to answer when they get back to the old country. I think it lies largely in the system of piece-work, which the American manufacturer views from a broader standpoint than the English operator. He says:—

"Earn, gentlemen, all you can. We will set a price, a fair price, and the more money you earn as workmen the better we are pleased. You are taking up a certain portion of space in our factory; that portion of space represents capital, because the fixed charges are the same whether you are doing much or little; therefore, the more work you perform the better it is for you and the better it is for me."

In Great Britain I do not think the manufacturers have adopted that attitude. They say that a British workman is entitled to earn about such and such an amount, and if, through his energy and his enterprise, he succeeds in earning larger wages, the manufacturers begin to say, "These men are earning too much. Good gracious me, this sum of money is hardly fitted to their position! We must cut the price," and the price is accordingly cut. And that system has gone on for generations, with the result that heart is taken out of the men, and they do not to-day, I believe, put forth their best energies, because they feel,—and rightly feel,—that their treatment has not been generous.

Another point that I think will have struck my delegates is this,—the encouragement that is offered by the manufacturers of the United States to the brains and the initiative of the workmen. They say to the workmen:—

"Tell us all you know. Do you see anything that you think can be improved? If so, send in those improvements to us and we will recognise them by payment either of a premium or by giving you a share in the saving that you make, or promotion, or some other remuneration which shall be equally satisfactory."

The result is that they have many brains continually working, seeking to improve the methods of their manufacture, seeking to give the manufacturers the benefit of their experience, and only the man who is working daily at the machines, and who is continually in touch with the practical part of the business, really sees what is going on and has the opportunity of improving the methods of manufacture. The man sitting in his counting house as administrator cannot improve. It is the body of the workmen that one must look to for suggestions and inventions.

The American manufacturer, recognising that, encourages the initiative of the men and rewards it. In Great Britain, I am sorry to say, I do not think manufacturers have taken that broad-minded view. They stand in the position of saying, "We know our business; we have nothing to learn; we require you there to do your work; do as you are told. We ask nothing more."

There is another point that also militates against the initiative of the workmen, and that is the jealousy of the foreman. The consequence is that the progressive workman is smothered; things are made too warm for him; he leaves. And it is such things, the impossibility of closer touch between the manufacturer and his workmen, the want of touch that Americans do not suffer from, that has brought about a state of crystallisation,

if I may so put it, between the manufacturer and his employees. It is a bad state of things. It is one that will have to be altered in Great Britain if we are going to hold our position in the markets of the world.

Another point that has struck me casually is American up-to-date machinery. You are continually encouraging your men to invent. And you do not view your machinery as part of your capital that must be kept there indefinitely. Directly there is something better you are ready to throw your machinery on the scrap heap and introduce something better, because it makes for cheapness of production, because it makes for the higher wages of the men. And consequently when the men are making higher wages, a larger amount of profit is going into the manufacturers' pocket.

I find here, as far as I am able to judge, as an amateur, that you are running your machinery at a greater speed than we are in Great Britain; you are getting more out of your machines, you are employing a smaller number of men in connection with those machines. I found, in going through American shops, machines being run,—six, seven and eight,—by one man. I do not think the workmen in Great Britain run the same number of machines with the same number of men, and there, I think, the unions are largely to blame. I do not blame the unions altogether, for, as I have just now said, it is because our employers do not recognise the merits of the men, and their title to a higher standard and to the higher wages, that they themselves have protected themselves, as it were, by not, perhaps, taking the very best out of machinery. It is a fallacy and one that will have to be dropped in the future.

But the workingmen will ask,—"What is our position? If we are prepared to run these machines at a higher speed to earn the full benefit that this machinery will give us, what is to be our share?" And I think they have a right to come to an understanding with the manufacturer as to what their share is to be. Again, there is the question of hours. There is more than one view to be taken of it in the United States. You have to ask yourselves, what is the position in other countries? It is useless for the United States to seek an ideal of an eight-hour day if Germany is going to work ten. It means that the markets of the world will be glutted by the manufactures of the country whose workday is longer than that of the United States. We most come into line if there is to be any real progress in that.

We hear a great deal of restriction of output, boycott, unions, free labour, etc. Restriction of output is, to my mind, a fallacy the world over. It cannot be encouraged, it cannot be permitted. I do not think the intelligent workmen of any part of the world encourage it. Our workmen who have been here,—the representatives rather of the workmen,—deny that there is any restriction of output in the old country. I am delighted to hear that they do so. They deny that there is any of the "go-slow" plan. I am delighted they take that attitude. It makes for better things.

The boycott is a thing that does not appeal to anyone. Free labour is a sacred proposition that must be protected, not only by the workman, but by everybody who desires freedom in any country. A man must be free to sell his labour to whom he pleases, whether he belongs to the unions or not. I myself am in favour of unions; I have shown that by the people I have brought to this side of the water. But while I favour unions I do not favour all that trades unionism does. There must be a perfect right for a man to join a union without intimidation. He must be interfered with by no one. The same applies to the free labourer who wishes to sell his product, his hand-work, to any manufacturer. He must be free to do so unhindered, unincumbered in every shape and form; and were I a manufacturer, if any attempt were made to interfere with that freedom in my factory I would fight it to the bitter end. I would close my factory rather than submit to it. Trusts have been very much abused in America from the

standpoint of those who have not sufficiently looked into the proposition. Personally, I do not view trusts with any distrust. I think they are leading toward a better state of things, both for the manufacturer and the workingman. Capital and labour are partners, and the sooner both capital and labour of all grades really realise that proposition, the better for the community at large. They are partners just as much as man and wife, and if you attempt to divorce them it brings trouble and breaks up happy homes.

JOHN HAYS HAMMOND

A BIOGRAPHICAL SKETCH

AT the time of the notorious Jameson raid in South Africa, half a dozen years ago, popular interest in this country was largely aroused by the fact that among those who were arrested and sentenced to death as a consequence of that expedition was John Hays Hammond, a member of the American Institute of Mining Engineers, and a widely known member of the profession. Mr. Hammond was one of the four leaders in the reform movement in the Transvaal from which the Jameson raid resulted, but with this latter he was not in sympathy, and his sentence was afterwards commuted to fifteen years' imprisonment. Eventually, however, he was released on payment of a fine of $125.000.

Mr. Hammond was born at San Francisco in 1855, and after preliminary training at the Hopkins Grammar School, at New Haven, Conn., entered Yale University, taking the degree of Bachelor of Philosophy in the Sheffield Scientific School in 1876. A few years ago the honorary degree of M. A. was conferred on him by Yale University. He also studied for three years in the Royal School of Mines, at Freiberg, Saxony. On his return to America in 1880 he was appointed as special expert on the United States Geological Survey and Mineral Census to examine the gold fields of California. In 1892 he went to Mexico and superintended the large silver mines at Sonora, subsequently returning to California and becoming consulting engineer of mines in Grass Valley. He was also consulting engineer to the Union Iron Works, of San Francisco, and the Central Pacific and Southern Pacific railroads.

In 1893 Mr. Hammond went to South Africa as consulting engineer to the mines of the Barnato Brothers, of London. In 1894 he made an expedition, in company with Cecil Rhodes and Dr. Jameson, into the country now known as Rhodesia, and made a report on the mineral resources of that country for the British South Africa (Chartered) Company. The result of this visit was a great stimulus to the development of the mines of that section. He was a strong supporter and admirer of Cecil Rhodes, and subsequently became consulting engineer to the Consolidated Gold Fields of South Africa, the British South African Company, and the Randfontein Estates Gold Mining Company. He was one of the first to advocate the development of the deeper areas of the Witwatersrand mining district. As consulting engineer of important mining companies in South Africa, Mr. Hammond gave employment to many Amer-

ican mining engineers, and was instrumental in having orders for hundreds of thousands of dollars worth of mining machinery placed in the United States.

Since returning to America, where he intends now to reside permanently, he has travelled extensively throughout the West and Mexico, examining mines. He has also found time to lecture at several universities.

Current Topics

ONE point which has been made by trades unions in opposing the premium plan of paying wages is that the increased productive capacity of the workman, resulting from the shortening of the time required for any particular job, should count wholly in his favour; in other words, the time saved by him should be paid for in full by the employer, and the latter should not, as the premium plan provides, have a half share or a third, or any other proportion, in its money equivalent. By taking such a share, it is contended, the employer is really imposing a fine on the workman for increased production. In having this claim made for him, however, the workman ignores the fact that his increased production is not due simply to his own efforts. However well directed these might be, they would serve him only in part were it not for the right kind of machinery with which to exert them. The best automatic tools, the prompt discarding of machines not entirely up to date, the best possible lighting facilities in a shop, a superior shop system of handling work in transit,—why should not things like these be entitled to a share in the increased profits in output? They represent the employers' efforts in lightening the work, the employers' expenditure of brains and capital, and in many instances their productive effect is the real effect, while the workman's is only in small part tributary. Clearly if the workman's capital, – his labour, in other words,—is to bear increased interest, the employer's capital, too, should have that advantage.

WHILE almost every trades union official is up in protest the moment you state what everyone knows to be true, that restriction of output in almost every shop where union workmen are employed is systematically practised through the loafing of the men, exam-

ples by the score are available to prove it. A very good one was supplied recently by Mr. Marcus M. Marks, the president of the National Association of Clothing Manufacturers of the United States, in an address made to the National Civic Federation at New York. Mr. Marks told of a certain establishment where the men, for a comparatively long time, had been earning regularly four dollars a day. They were employed on piece-work, but they had evidently agreed among themselves, as subsequent events proved, that none of them should try to earn more than that. At a certain time, for some reason without any bearing on the matter of wages, the men went on strike, and their places were filled by new men, comparatively inexperienced in that particular branch of manufacture. These new men also were paid by the piece, but because of their supposed lack of proficiency, were paid 25 per cent. less per piece than the old hands. At the end of a week's time the startling fact presented itself to the employer that the new men were earning, on an average, nine dollars a day The conclusion that his former employees had willfully idled away more than half their time was inevitable. It was a bit amusing to hear on that same occasion, within the succeeding half hour, the dramatically uttered statement by the president of the American Federation of Labour that the great trouble with the workingman at the present time was that he worked entirely too hard. The resulting laughter that swept over the audience must have sounded unpleasantly derisive to the ears of the attending representatives of organised labour.

WHILE much has been said and written about the sprinkling of oil on roads, principally as a means of preventing dust, the use of the oil in the same way on river levees in some parts of the United States is said to have been found to be an excellent protection against the burrowings of gophers and ground squirrels, which threaten the security of the barrier raised against the encroachment of the flood waters. Crude oil is so distasteful to these pests that they shun the ground covered with it. In one instance experiment is said also to have proved that an oil covering to the levees forms a safeguard against the damaging effects of the lapping of the flood waters, as the latter slide harmlessly up and down the oiled surface of the bank.

THE illustration on this page tells more briefly, and perhaps quite as clearly as words can do it, how one inventor proposes to generate electricity for railway train lighting. As in the case of what has been termed the "axle light," the motion of the train here also is to be used to furnish the requisite power; but this, instead of being taken from the car axles, is to come from a rotary fan on the front end of the locomotive, driven

THE ROTARY FAN DRIVES A DYNAMO FOR LIGHTING THE TRAIN

by the more or less violent gale of wind created either by the train itself when in motion, or, at any rate, augmented by it. The dynamo, located on or under the pilot, is to be driven from the fan through chain gearing, and an electric

accumulator is to be provided underneath each car to store up current at favourable times. Tests are said to have been made with an outfit of this kind, and the results are said also to have been encouraging, contrary to what one might be led to expect. But whatever its practical value, it will, perhaps, be admitted that the proposed equipment possesses the charm of novelty. It is being exploited by a Chicago firm,—the Western Ventilating & Lighting Company.

ONE of the early experiments with petroleum as fuel for naval uses is described in the *Army and Navy Journal*, of June 22, 1867. Eight days before that date the United States steamship *Palos*, a small gunboat, which had been fitted with apparatus for burning oil, left Boston navy yard and made a trip of twelve and a half miles to sea and return in one hour and fifty-five minutes. In forty-eight minutes she ran eleven and a half knots, whereas her best record with coal as fuel was eight knots an hour. When using coal the *Palos* required twenty firemen and coal passers, but with oil she needed only three men in the fire room. The petroleum was supplied from two large iron tanks placed on deck, each with a gauge at its side to indicate the contents, and a vent pipe on top to permit the escape of vapour. From these tanks the petroleum was conducted by half-inch pipes to the boiler furnaces. There it dropped into heated retorts of iron and was instantly vapourised. This vapour was burned under the boilers after being mixed with steam which had been decomposed by passing it through pipes partly filled with iron filings. To this mixture or vapourised petroleum and decomposed steam there was also added a percentage of oxygen supplied by atmospheric air forced in by an ordinary air pump. "The heat thus generated," says the report of 1867, "is intense, and it is a noticeable fact that the combustion is so perfect that no smoke is perceptible. A diminution of the supply of air or steam at once creates a smoke."

FROM time to time the statement is made that suspension bridges are things of the past, and that cantilever and other structures have superseded them. As an instance of this a correspondent of one of the New York daily newspapers recently maintained that "when the problem of really consolidating the city of New York with its great neighbouring cities, to the east and west, is really taken in hand, it will not be solved by suspension bridges, typical of the engineering of the early years of the last century, but rather by tunnels or by great steel tubular and girder structures, which will link the railroad systems, as well as the thoroughfares of the cities." As to this, however, it is proper to point out that the old form of suspension bridge is an antiquated, superseded structure in exactly the same way that all old designs are antiquated and superseded. It is not the principle that is wrong; it is that the details are behind the modern methods of construction. To eliminate the suspension bridge from modern work is to deprive engineers of a form of construction which has special adaptations and which modern science cannot afford to give up. Six years ago Mr. George S. Morison, in a paper presented to the American Society of Civil Engineers, stated that fifty years previous to that date the suspension bridge was regarded as the one class of structure adapted to spans of unusual length. Highway suspension bridges were built in almost all parts of the world; several railroad suspension bridges were proposed, and the one actually built across the Niagara River has done service for nearly forty years. Fifty years ago metallic bridge construction was in its infancy, and anything beyond the limit which could well be built of wood was considered an exceptional span. Although there were a few striking exceptions, 200 feet was practically the limit of wooden truss bridge spans.

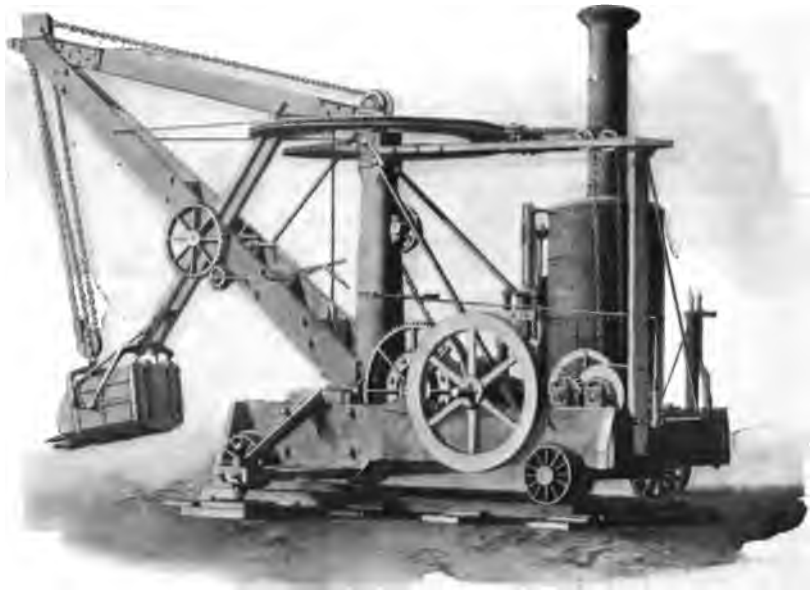
THE introduction of iron bridges changed these conditions, and a 400-foot iron span was as readily built as a 200-

foot Howe truss. The first 400-foot span in America was constructed by Albert Fink, past president Am. Soc. C. E., in a bridge across the Ohio River at Louisville, Ky., where it is still in use. The cheapening of the price of iron, the increased capacity of rolling mills, and the new methods of making steel have rendered it an easier task to build a truss of 600-foot span now than it was to build a 400-foot span then. The result of this development has been that trusses have superseded suspension bridges, and where a suspension bridge would have been built forty years ago, a steel truss is now put up. Furthermore, the old suspension bridges were highway bridges, and highway traffic does not enter upon a bridge as a concentrated load, while it is generally light in proportion to the dead weight of the bridge. Important modern bridges are generally railroad bridges, and the suspension bridge has not been considered stiff enough to serve this purpose, this want of stiffness being largely due to the fact that on a single-track railroad bridge the whole moving load comes on as a concentrated load, and that on railroad bridges of modern span the moving load is large in proportion to the dead load.

No important suspension bridge has been built since the East River Bridge, connecting New York and Brooklyn, the design of which was shaped by the elder Roebling before his death in 1869. Since then great advances have been made in all other forms of bridge construction. While it is admitted that there is no field for suspension bridges of the dimensions of which they were formerly built, a new field is opening in structures of enormous size. If, at the present day, an 800-foot span is to be built, a truss on the beam or cantilever principle would be used; but a 2000 or 3000-foot span would be a case for a suspension bridge. Two things must be remembered. In a suspension bridge of any such enormous size the dead weight would be large in proportion to the live load, and the distortion due to the passage of trains would be comparatively small. Such a bridge would be built for two or more railroad tracks, its length would be much greater than that of a single train, and the condition under which a concentrated maximum load would advance as whole upon the bridge would be rare. In the manner of the passage of loads such a bridge would resemble a highway bridge more than a short-span railroad bridge. Before, however, a suspension bridge is built which will bear the same relation to the modern steel truss that the old suspension bridge did to the wooden truss, the same advance in details must be made in suspension bridges that has been made in truss bridges. If such a bridge is to be built now, the designer must concentrate in the work of a single design all the improvements corresponding to those which truss bridge builders have spent many years in developing.

THROUGH the courtesy of Mr. Isaac Otis, of Clifton Station, Virginia, it has been made possible to present on the next page a photographic reproduction of one of the earliest steam shovels ever built,—one of two that were made in the United States in 1841 and were sold to Russia. The machine, we are told, is, indeed, identical with the first steam shovel made in the same year, except in so far as the engine is concerned, which, in the original machine, had an upright oscillating cylinder. The inventor of this shovel was William S. Otis, and of him and his work Mr. Isaac Otis, his brother, has supplied the following interesting particulars. While without mechanical training, his attention was at an early age attracted by the possibilities of excavating by steam, and when twenty-two years old, in 1836, he secured a patent for what he called his "American Steam Excavator." In those days boilers and engines were large and clumsy, and young Otis found it necessary, therefore, to design and build a special upright boiler and engine combination which is used to this day in the Otis excavators. The first one

of his machines was built at Philadelphia by the firm of Easton & Harrison, two young men engaged principally in locomotive building. This machine was used in a variety of work in different places, part of its performance being in Canada in connection with the digging of the Welland Canal in 1843, and while it. Colonel Whistler, the father of the celebrated artist, at that time chief engineer of the Boston & Albany Railroad, then called the Massachusetts Western, was much interested in the working of the first steam excavator, so that when he was called to Russia to survey the St. Petersburg & Moscow Railroad he



AN EARLY STEAM EXCAVATOR. MADE BY WILLIAM S. OTIS IN 1841. THE FORERUNNER OF THE MODERN STEAM SHOVEL

there employed it was guarded by a company of British soldiers, as the workmen threatened to destroy it. They called it the "Steam Paddy," and it is told that one day a drunken Irishman, after witnessing its operation for some time, shook his fist at it and exclaimed, "Be jabers, ye can dig, but you can't vote." This machine, after widening the "Big Cut" above water, was put into a boat and used with success in deepening the channel. Later it was removed to Buffalo, where it served for many years in dredging that harbour. Otis did not live long to enjoy the fruits of his invention, dying when only twenty-six years old. One of the machines was sent to Great Britain in 1841 or 1842, but at that time British contractors would have nothing to do with caused the government to purchase two of these machines for use in the construction of that road.

To the statement made in an article on the use of the steam shovel in mining, in the September, 1902, issue of this magazine, that "the modern steam shovel is the product of evolution,—a growth from a crude beginning to a high development," Mr. Isaac Otis objects vigorously. "The present steam shovel," he says, "represents principally an enlarging and strengthening of the original machine, which worked as perfectly with its limited power as the larger ones of to-day; and the record of two of these machines with single 10 ×

12-inch engines, and dippers of 1½ cubic yards capacity, used by Dillon, Chapman & Clyde in filling the great trestle, requiring over a million yards, on the Lake Shore road at Girard, Pa., U. S. A., has never been surpassed. This work in 1856 was taken at a low price, which would have ruined any contractor using hand labour, but which yielded a large profit to the contractors in question. The Mr. Dillon of the above firm was Sidney Dillon, one of the builders, and afterwards president, of the Union Pacific Railroad." In conclusion, Mr. Otis says that "all steam shovels to-day use the swinging crane, operated in a three-quarter circle, and the hoisting and thrusting motion of the dipper, all embraced in William Otis' first machine." The illustration helps, in a measure, to bear out Mr. Otis' contention.

To burn bituminous coal without smoke, says *The Locomotive*, has long been the hope of inventors and engineers, for it is generally admitted that an enormous waste occurs when any considerable amount of smoke issues from the chimney. It is true that smoke is a sure indication of imperfect combustion, but the vapour ordinarily seen coming from the chimney is not all smoke. The dense black smoke sometimes seen consists almost entirely of unconsumed carbon, but the composition of the lighter smoke is very different. Most coal contains a considerable quantity of moisture, especially bituminous coal; and this moisture is, of course, evaporated by the heat of the fire, and driven off as steam, in company with other products of combustion, giving the light vapour usually seen issuing from the chimneys. Even the densest smoke contains but a small quantity of unconsumed carbon, as measured in pounds, though it is likely to contain a considerable quantity of invisible gases that would have been burned and utilised had the combustion been more perfect. The black smoke is usually given off when long flames of a yellowish or reddish hue lap along the whole length of the boiler and perhaps pass into the flues. When the damper is right, and the draught good, and the fires are well laid, so that all parts of the grate are evenly covered, the lazy, smoky flame is changed to a short flame of intense brightness. Too much air is as capable of producing smoke as too little; for by its chilling action it makes perfect combustion impossible, and causes the same dense cloud to appear at the stack. In charging fresh coal it is a good plan to leave the furnace door ajar slightly until the fire has burned up a little so as to admit an extra supply of air, that which passes up through the grate being checked for a few moments by the fresh fuel. If the door is kept wide open the boiler will be cooled down and may be severely strained, and a big column of cold air will pass right over the fire in a body, and up the chimney; but if the door is kept half or three-quarters of an inch ajar, the air that is admitted will distribute itself through the furnace pretty uniformly, and will consume the gases given off by the fresh coal. As soon as these gases burn off, the door should again be tightly shut.

In contrast with the irrational opposition which most trades unions have shown to incorporation of their associations and their consequent legal responsibility, it is pleasing to note that one American labour organisation,—the Lake Carriers' Association,—recently took preliminary steps towards their incorporation in one of the States of the Union, with moderate capitalisation. According to report, measures also were taken by them to urge the longshoremen and other labour organisations with which they have to deal likewise to incorporate, and the favourable action in this matter of these bodies would go a long way towards increasing public respect for them. To say that labour organisations do not wish and cannot afford to become incorporated bodies, and that they decline to become responsible to anybody for anything,—a public statement recently made by one of the

leaders of American trades unionism,—can be characteristic only of intentional law-breakers, and against the imputation of being such union workingmen ought to be happy to defend themselves by just such means as incorporation places at their disposal.

THERE are probably few places of corresponding dimensions where electricity and electrical apparatus are so extensively and variantly employed as on board a well-equipped modern war vessel, and it may be added that there are few, if any, other instances where the use of electric power has been so rapidly increased. Lieutenant George of the United States Navy, in a recent paper read before the American Institute of Electrical Engineers, makes some interesting comparisons which bring out this fact quite clearly. For example, he points out that the *Trenton*, of the United States Navy, was the first man-of-war in the world that was lighted by the incandescent lamp. This was in 1883. The electric equipment of the *Trenton* consisted of a 12-kilowatt dynamo, which generated electricity for one hundred and fifty 16-candle-power lamps. In 1895 the battleship *Indiana* was equipped with dynamo machines aggregating 67 kilowatts capacity, while in 1900 an electric plant having a capacity of 655 kilowatts (877 horse-power) was installed on the battleship *Kearsarge*. This equipment of the *Kearsarge* compares very favorably with the representative vessels of the German, Russian and French navies, which have generating plants of 325 kilowatts, 588 kilowatts, and 295 kilowatts, respectively. The steam engines, dynamo machines, switchboards, and indicating instruments of such plants comprise a central station capable of supplying the needs of a fairly large town. From this station electric cables of the most approved make run to every part of the vessel, conveying all the electric power necessary to operate hundreds of incandescent lamps, searchlights, and dozens of electric motors, ranging from one-twelfth of a horse-power to 50 horse-power. These electric motors are used to drive fans, fixed and portable, also the ventilators of the main ventilating system, and for ammunition hoists, for chain hoists of turret guns, for elevating and depressing the guns, and for ramming the shell into the breach. The turrets themselves, weighing, with their load, over 600 tons, are turned by 50 horse-power motors, and motors of similar size are employed to operate the boat cranes. Electric motors are also employed in the more menial capacity of driving air compressors for operating other contrivances. As a means of communication between different parts of the ship electric call bells, annunciators, and telephones are liberally employed. There are also electric fire alarms, which automatically announce, by the dropping of a small shutter, to the captain's orderly, a temperature in excess of 100° F. in any of the magazines, coal bunkers or store-rooms. In addition, there are electric general alarms, warning signals, engine room telegraphs, steering telegraphs, and numberless other electric indicators and signaling methods, and last, but not least, a wireless telegraph system. It is almost unnecessary to add, in view of the foregoing, that all modern war vessels are also equipped with an up-to-date electrical library.

OF the right to a minimum wage, for which trades unions everywhere are strenuously working, *The Iron Age* aptly says that labour has not any more right to this than there is a right to a minimum return on capital, be it in the form of interest or profit. If a man has put his money into a business which does not pay, he must draw it out as best he can, or, failing in that effort, lose it. If labour cannot get adequate remuneration in one occupation, the surplus crew must turn into other channels of work. That may mean suffering in both cases, but such is life. Little sentiment is wasted on stricken capital, but there is endless shedding of tears over labour and an amount of sentimenta

coddling which is not alone misplaced, but also dangerous to the victim, since it twists the ideas of workingmen.

Up to the year 1900 the almost universal design for a steam piping system for power plants, as told by Mr. William Andrews in a recent paper read before the Engine Builders' Association of the United States, was to carry a pipe for each boiler into a large steam header, the cross section of which was equal to the sum of the areas of all the feeding pipes. If the designing engineer wanted to be very grand he made it larger without knowing just why. From this header, pipes were carried to the various engines, of sizes called for by the engine builder. It was quite common to place steam separators in each line leading to an engine, but fashions changed in steam piping, as well as in clothes, and with the advent of high pressure and superheated steam sizes of pipes have been very much reduced. In the four large power houses now built in New York City, with an ultimate capacity of from 60,000 to 100,000 horse-power each, the largest steam mains are not over 20 inches in diameter, and these are used more as equalising pipes than storage reservoirs. Some of the best plants have pipes which run from the header to the engine two sizes smaller than that called for by the engine builders. These pipes, before reaching the engine, are carried into a wrought iron or steel receiver, which acts also as a separator. This receiver has a cubical capacity three times that of the high-pressure cylinder, and is placed as near as possible to the cylinder. The pipe from the receiver to the cylinder is of the full size called for by the engine builder. The object of this arrangement is, first, to have a full supply of steam close to the throttle; second, to provide a cushion near the engine on which the blow caused by the cut-off in the steam chest may be spent, thereby preventing vibrations from being transmitted through the piping system; and, third, to produce a steady and rapid flow of steam in one direction only, by having a small pipe leading into the receiver. This steam flows rapidly enough to make good the loss caused during the first quarter of the stroke. Plants fitted up in this way are successfully running where the drop in steam pressure is not greater than four pounds, although the engines are 500 feet away from the boilers. This is probably the most radical departure in high-pressure work up to the present time. Allowance for contraction and expansion is provided for by long bends, by using a double swing, like a gas bracket, on which the fittings turn on the threads of the nipple, and by producing what may be called initial tension. This can hardly be described in words, but is a rule-of-thumb method by which the skilled steamfitter puts a strain on the pipes when cold, so that when the pressure is put on, the expansion removes this tension and there remains no strain on the pipe other than that due to internal pressure. Expansion joints of the old slip style, or those made of corrugated copper, have entirely disappeared from the modern first-class job.

As to quality of material, in the earlier days of electric light and railway plants, owing to the difficulty of keeping the screwed joints tight, some engineers tried flanged cast iron pipe for steam mains, but it was heavy and clumsy and sometimes cracked on account of the unequal expansion. Then came copper, and this pipe, even when reinforced with steel wire, wound around it, was found to be a treacherous metal. Flanged cast steel pipe was tried, but the difficulty of obtaining this free from blowholes barred it out. At present the material used is either wrought steel or wrought iron pipe, on which the flanges are either riveted, screwed, or welded. In Great Britain and on the Continent they weld a light flange to the end of the pipe and face it; it is pulled together when in use by a heavy steel or cast iron flange which has previously been slipped over the pipe, very much as copper joints are made in marine piping. In

1880 the New York Steam Company installed about six miles of steam mains under the streets of the city of New York for power and heating purposes. All the joints in this pipe above 8 inches in diameter were made by expanding the pipe into recesses in the flanges, and then beading the ends of the pipe over the edges of the flanges. This was done by machinery, and was well done, and at the time was considered a great improvement over threading or riveting; but in five years every joint had to be taken out on account of leaks, and threaded joints were substituted. These threaded joints lasted until 1895, when all the pipes were renewed with new mains having heavy wrought steel flanges welded on the pipe. These welded flanges, when turned true in the lathe, make the most workmanlike and perfect steam joints in use at the present time, and their cost alone prevents their general use. Corrugated copper gaskets, placed inside the bolts and well pulled up, will make a joint which will last as long as the fittings. The softer gaskets containing rubber, asbestos or lead alloys need constant attention, and when superheat is used they are rapidly destroyed. When the owner's bank account is strong enough, ground joints without any gaskets are used. These make a first-class job, but the price is all but prohibitive. One of the very necessary points of a first-class piping job, and one which is very often overlooked, is to have extra heavy fittings on the gauge, lubricator and high-pressure drip connections. A break in one of these pipes, while it may not shut the station down, would cause great inconvenience, and would be a nuisance until it was fixed.

As one of the incidents of the more economical generation of steam which has been conspicuous in recent years, Mr. E. H. Sanborn, in his recent report on motive power appliances to the twelfth United States census, mentions the wider use of economisers for saving the heat of escaping products of combustion for raising the temperature of feed-water and the use of mechanically induced or forced draught. The large number of steam plants of great capacity which have been constructed in recent years in connection with central electric lighting stations, street railway power houses and large industrial plants has tended also toward the introduction of many economies for which there is neither necessity nor opportunity in small steam installations. The enormous quantity of coal and ashes to be handled in large steam plants permits the use of mechanical conveyors with marked saving in the expenditure for hand labour. In this and many other ways the arrangement and operation of large power plants has been reduced to a far more economical basis than ever before attempted, and careful study is now given to small details which formerly were considered of little consequence. All of this is the result of the constantly increasing magnitude of industrial operations and the prominence which is thus given to details formerly overlooked in small undertakings.

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CASSIER'S MAGAZINE

VOL. XXIII FEBRUARY, 1903 No. 4

GOLD MINING IN WALES

By W. H. Booth

IT was recently remarked in the city of London that one tithe of the money wasted on foreign gold mines, if expended in Wales, would have established gold mining in that principality on a firm and extended basis. Investors would at least have had the opportunity of readily ascertaining for themselves the extent of their properties and whether the glowing accounts of progress had any foundation in fact.

Though little known, gold has been mined in Wales for many years. When the subject was first suggested to the writer it was accepted with the idea that while there was gold to be found in Wales, its presence was of merely academic interest, and in no sense of industrial importance. Hardly had the necessary enquiry been made before the subject began to appear in quite a different light.

On investigation, it appeared that Barmouth, or, as it should be called, Abermawddach,—at the mouth of the Mawddach,—was a good point whence to start on local investigation. Standing on the bridge which crosses the estuary at this point and looking east, the gold-bearing country is seen on the left, extending along the right or north bank, the lodes occurring in the hills which slope down to the estuary in succeeding spurs from the range, rugged and many-coloured. It is a scene of singular beauty and impressiveness, especially when, as so frequently occurs, the cloud-compelling heights of Cader Idris to the south are capped in darksome thunder and hidden from view by a mingled downpour of mist and rain, contrasting with the sunlit slopes and wooded dells of the north bank. In this scene of beauty gallant little Wales hides her treasures in the quartz lodes

"DOES IT PAN WELL, JOHN?"

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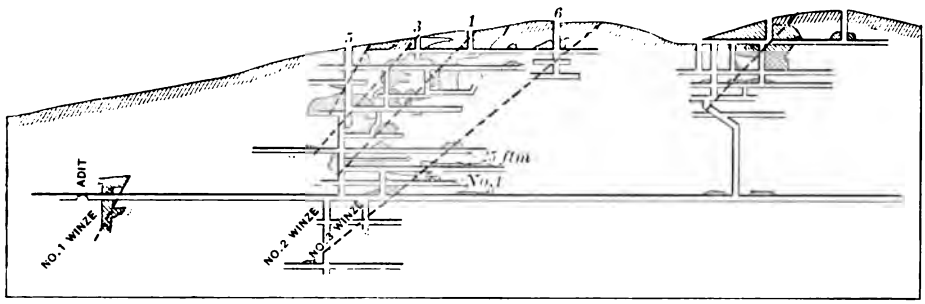
A GENERAL VIEW OF THE GOLD MINING PROPERTIES

that so numerously intersect the area of the Maentwrog beds.

The rocks of the gold-bearing area are Lower Silurian or Upper Cambrian, through which numerous masses of diorite thrust themselves. To these volcanic intrusions, one may suppose, the metalliferous lodes owe their riches. The dip of the strata is very high,—75 to 90 degrees,—and the quartz lodes are thus vertical, or nearly so, and are traceable on the surface by the prospector from point to point. Of the three mines more particularly referred to in the sequel, the Clogau is the most westerly and lies five miles in a north-westerly direction from Dolgelley; the



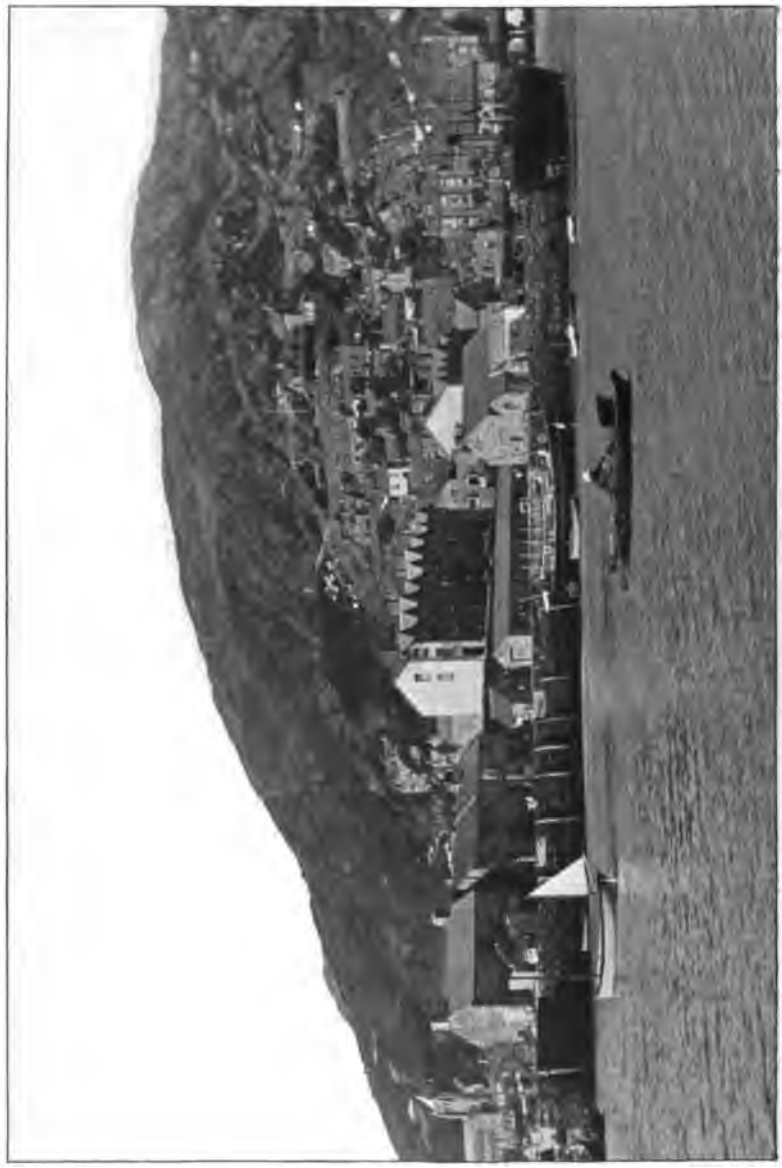
A SECTION OF THE ST. DAVID'S GOLD AND COPPER MINE. THE DOTTED LINES INDICATE THE DIRECTION OF THE GOLD SHOOTS

Voel mine is barely two miles in nearly the same line; and the Gwyn-fynydd is seven miles north of Dolgelley beyond the confluence of the Eden and Mawddach.

The Clogau is now more particularised as the St. David's gold and copper mine. Mining in the Clogau Mountain is supposed to have been carried on by the Romans, if not, indeed, started by them. They worked the lead ore on what is now known as the Blende lode, and old smelting hearths and slag can be seen to this day.

Coming down to more recent times, from 1836 to 1840, copper ore was discovered in paying quantities, and, in the year 1845, this mine was, with another, named the Vigra, worked by one James Harvey. At the same period a fresh lode was found on the Clogau and named St. David's. It was in this lode that the miners found what they called a peculiar yellow metal, not suspecting gold. A test was made of four tons, and the gold was ascertained to be in payable quantity. Expensive plant was put down, but official incapacity proved the ruin of the undertaking, and the concern finally came into the clutches of the Court of Chancery. Some years elapsed before Mr. I. A. Readwin, of Manchester, and Mr. J. C. Goodman, of London, became owners of half the mine by purchase, the other half being purchased by a Mr. Williams, of Dufffryn, Merioneth. They worked the St. David's lode for copper, but made a big discovery of gold in the shape of the stuff brought to grass for years previously. This was picked over and gold was recovered to the value of many thousands of pounds. Indeed, one ton alone is said to have yielded £6000, and the product of a small stoping gave, in all, £90,000.

In 1858 Mr. Williams formed a company to carry out work on a larger scale. and, in the year 1860, they crushed 80 tons of ore and gained 640 ounces of bullion. From 1862 to 1863 a little over 800 tons were treated and yielded 6243 ounces of gold. At this time £5 shares sold for £47 each. The management again changed and so did the treatment. Failure resulted, and plant, that had cost many thousands of pounds, was sold as scrap, and no further work was done until, in 1876, a company was formed by Powell & Milford, but came to a stop from lack of knowledge and



A VIEW OF BARMOUTH

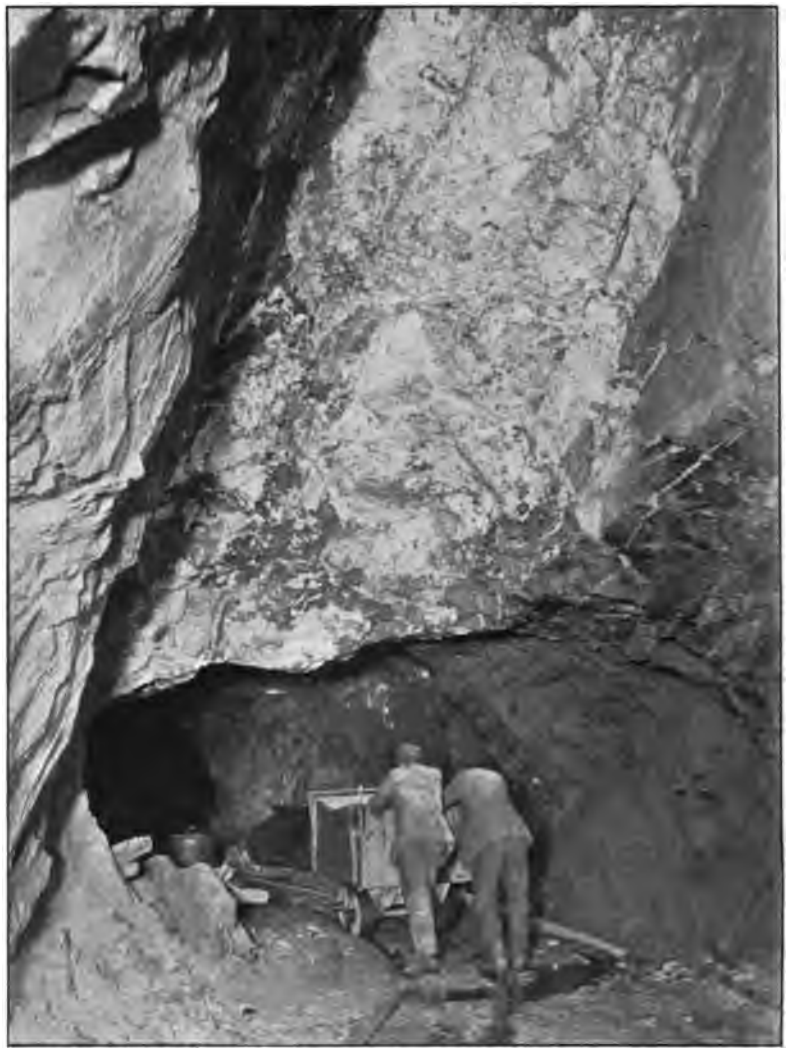
management, when the mine fell into the hands of Mr. I. E. Vickers, of Sheffield. He allowed a number of working men to work the mine on tribute, but finally formed a fresh company.

Much work was done, deep adits were driven below the St. David's for a length of three-fourths of a mile, and good ore was found; but again success was not secured, and the company was wound up and the mine closed until 1891, when Mr. Vickers sold two-thirds to Captain Thomas Evans, who was acting on behalf of four tradespeople of Barmouth, and worked very successfully for two or three years. The present company then bought the mine from them and put it into its present shape, with Mr. Wright as manager.

Mr. Wright has made a life's study of Welsh mining and has prospected the gold-bearing area thoroughly; he has faith and energy and backs his own opinion. As a start, a small plant was put down to crush samples only from all parts of the developed mine. The results were satisfactory, and a battery of thirty head of 1050-pound rotary stamps of latest design was ordered, together with a concentrating plant for recovering the copper in the quartz. Twelve months of work showed an average yield of 15 dwts. per ton. Here was business, and twenty additional stamp heads were put in hand, but the concentrating plant was removed, the nature of the copper ore being such as to make it unsuitable.

The mill lies a little off the road leading from Barmouth to Dolgelley in a narrow and picturesque glen, out of the side of which it was necessary to blast 10,000 tons of rock to make standing room for the mill. To the engineer, the roar of the stamp battery is a sound not to be confused with any other. It is as much *sui generis* as the racket of a thousand looms, or the burr and stamp of the well driller, and to approach this roar in the peaceful, quiet seclusion of a Welsh valley is indeed strange. Men of sense do not run a fifty-stamp battery

A STREET IN DOLGELLEY



IN THE ST. DAVID'S MINE

for fun, and the sight of these fifty heads in ceaseless, measured thunder is nearly as convincing of the actuality of Welsh gold as it is to watch the tables and note the accretion of little spots of amalgam showing where the gold is being greedily licked up by the plates.

The mill buildings are modern framed corrugated iron structures, neat and sufficient,—not extravagant. In seasonable weather, which means wet weather to the gold miller, all the plant is run by water-power, with a Pelton wheel of 190 H. P. under a head of 200 feet of water, piped from a distant reservoir. In the absence of sufficient water, a Tangye producer gas plant supplies gas to a Tangye gas engine of 135 B. H. P. and to the 50 B. H. P. engine of the oil plant, of which more anon.

There is also a standbye compound steam engine to drive compound air compressors when water is short. These were supplied by the Tuckingmill Foundry Company, of Camborne. Air is compressed to eighty pounds pressure

for rock drills and air winches, the former supplied by the Tuckingmill Company and the latter by Holmans, of Camborne.

An overshot water-wheel supplies power to drive the clean-up pans. The arrangement of the mill is such that there is no handling of the ore. It arrives at the mill in the buckets of an aerial ropeway, whence it is dumped over a grizzly, the fines going direct to the ore bins. The large lumps, which pass over the grizzly, go to a stone crusher and thence to the bins.

The reduced ore is fed from the bins by automatic Challenge ore feeders and vibrated circular feeding plate, by which it is slowly dribbled into the stamp box and crushed, the stamps falling about 8 inches at each blow and the cam shaft this millhouse is particularly striking as a roomful of good machinery in excellent order. The fronts of the boxes are closed grates of perforated 35-mesh steel sheeting, through which, when fine enough, the crushed quartz escapes with each blow of the stamps. As each box holds five heads, there are ten boxes in all, and the stamps drop in the approved order of 1, 3, 5, 2, 4.

A constant stream of water is run into the stamp boxes and is splashed out with the finely crushed stuff through the grates, flowing in a thin sheet over the slightly inclined tables, which extend about 8 feet in front of the stamp boxes. The usual amalgamating table is covered with copper plates, which are held down tightly on the table with edge strip packing of blanket so as to minimise

THE ENTRANCE TO THE MINE AT GWYN-FYNYDD

making about forty revolutions per minute, so that each stamp is dropped eighty to eighty-five times per minute. The stamps have solid steel shafts, and are of the free rotary type of Fraser & Chalmers' latest and best style. Indeed, the leakage. The plates are coated with mercury, a metal that is as greedy of gold as melted tin is of lead.

The smallest particle of gold coming in contact with the adhesive layer of liquid mercury on the plates is at once

THE VOEL MINES MILLS. THE GAS PLANT, INSTALLED BY MESSRS. TANGYES, LTD., OF BIRMINGHAM, IS SHOWN AT THE BACK, ON THE RIGHT. THE ORE GOES INTO THE MILLS FROM THE LEFT, THE BUILDINGS, TAKEN FROM LEFT TO RIGHT, CONTAINING STONE BREAKERS, CRUSHERS, JIGGERS AND VANNING TABLES

COMING OUT OF AN ADIT AT ST. DAVID'S

held fast, and in course of time the whole of the mercury becomes charged with gold. Mercury is the only metal that is liquid at ordinary temperatures and in contact with water. No doubt molten lead or tin would extract gold from dry, powdered ores with more or less success; but water allows the heavy gold to find its way to the surface of the table. It acts as a carrier and spreader of the powdered ore and helps to keep each particle of gold clean and free from dirt.

As the plates become charged they must be cleaned of their amalgam and fresh mercury rubbed on. This involves a few minutes' stoppage several times daily and a corresponding reduction of output. By means of interchangeable plates, — a new invention of Mr. Wright, —all stoppages are dispensed with, and, in a couple of seconds, the millman can change his plates, the charged plate being cleaned at leisure, recoated, and placed ready for the next charge. In this manner the output of the mill is maintained higher. Very little gold should fail to be picked up in the course of the first two or three feet of the tables, though a length of 5 feet of three movable plates is employed, with a further 3 feet of fixed plate beyond which the tailings are run to the Elmore oil concentration plant. The Elmore process,

THE GAS PRODUCER PLANT AT THE VOEL MINES. THE STEAM BOILER IS SHOWN AT THE RIGHT; THE SCRUBBER, IN THE CENTER; THE GAS HOLDER AT THE LEFT, AND THE GENERATOR AND COOLER ARE AT THE BACK, WITH THE CHARGING PLATFORM ABOVE. INSTALLED BY MESSRS. TANGYES, LTD., BIRMINGHAM

which has here shown undoubted proof of its satisfactory performance, comprises a series of revolving mixing cylinders in which the drained tailings from the mill are thoroughly incorporated with crude mineral oil so as to form a thick, treacly mass. Mineral oil has two peculiar properties in the case of mill tailings. It adheres to nearly all metallic sulphides, but it does not adhere to pure silica, which quartz is. The mixed mass is placed in shallow pans and subjected to water percolation. The water carries away the silica, but cannot detach the metallic particles from the sticky oil.

In time the oil becomes loaded with metal. It is then put into powerful hydro-extractors, of which there are four, and these throw off every particle of oil, leaving the now concentrated ore ready to be sold to Swansea smelters. The concentrate is chiefly copper and any gold that may have come over from the mills. The Elmore plant here has a daily capacity of 260 tons.

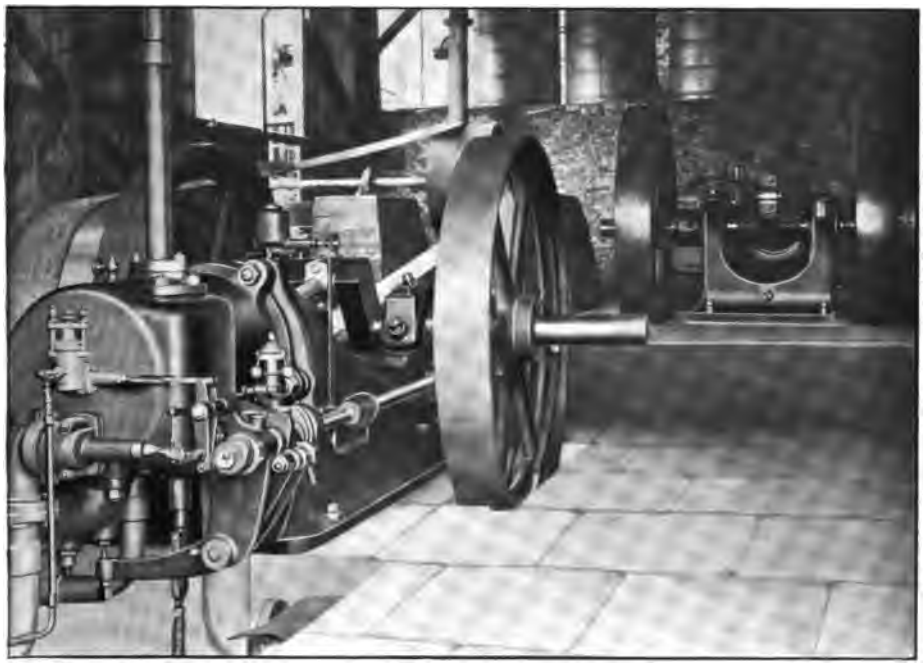
Speaking generally, with one or two exceptions the oil will stick to sulphide ores, but not to oxides. It serves the very useful purpose of separating copper pyrites from magnetic iron. The mixing up of the wet pulp with the oil must be sufficiently thorough to enable each particle of ore to touch the oil. The mixed mass then passes forward and the wet pulp at once gravitates out of the oil in the form, when the ore is a quartz rock ore, of white sand. The oil with its load of ore particles is then run into a 48-inch diameter hydro-extractor without perforations. In this the stuff is set in rapid rotation and every particle acquires a tendency to fly to the outer rim with a force proportionate to the specific gravity, but much magnified by the speed. The speed of rotation, in fact, gives energy to the metallic particles which enables them to overcome the adhesion of the oil, and, by means of warmth, the oil is made even less tenacious of its load. Water is also run into the extractor and dis-

poses itself as a vertical wall outside the oil, acting towards this as the skim milk acts towards the cream in a centrifugal separator. The oil is drawn off for immediate re-use. The ore round the rim of the centrifugal is emptied, after stoppage, into a 36-inch diameter perforated extractor, in which it is again "whizzed" to drive out the last of the oil. Very little oil is lost in the ore as finally delivered by the second centrifugal.

In the oil concentration process use is made first of the preference of sulphide ore for oil and of the silica (oxide of silicon) and most other oxides for water. The water-wetted particles fall out of the oil when the combined stream is run over a spitzkasten. Then comes the difficulty of destroying the adhesion of the oil, for it would not pay to burn this in smelting. Here the principle of accentuated gravitation comes in to energise the particles of ore to make headway out of the sticky mass and through the wall of water.

Why finely divided metallic ores will so readily float away on the surface of water appears to be due to some property of adhering to or otherwise occluding a minute quantity of air. Carbon and platinum both possess the power of occluding certain gases, and it is quite possible that metallic ores have a similar property. Certain it is that this floating stuff will sink in boiled water, from which it may be supposed that the air has been driven off.

It might be added as regards the amount of ore that oil will pick up that this is limited in the Elmore process to that weight which would begin to render the oil too nearly as heavy as water to float. In explanation of the separating action of the centrifugal machines it should be stated that these are run to give an effect eight times that of gravity. It would thus appear that the air attached to each little flake of ore will be compressed in the centrifugal to a fraction of its ordinary volume and will be deprived by pressure of its power to



GAS ENGINES AT THE VOEL MINES, INSTALLED BY MESSRS. TANGYES, LTD. THE ONE AT THE FRONT, TO THE LEFT, IS A 50 B. H. P. ENGINE, AND THE ONE AT THE BACK DEVELOPS 75 B. H. P.

A STOPE IN THE GWYN-FYNYDD MINE

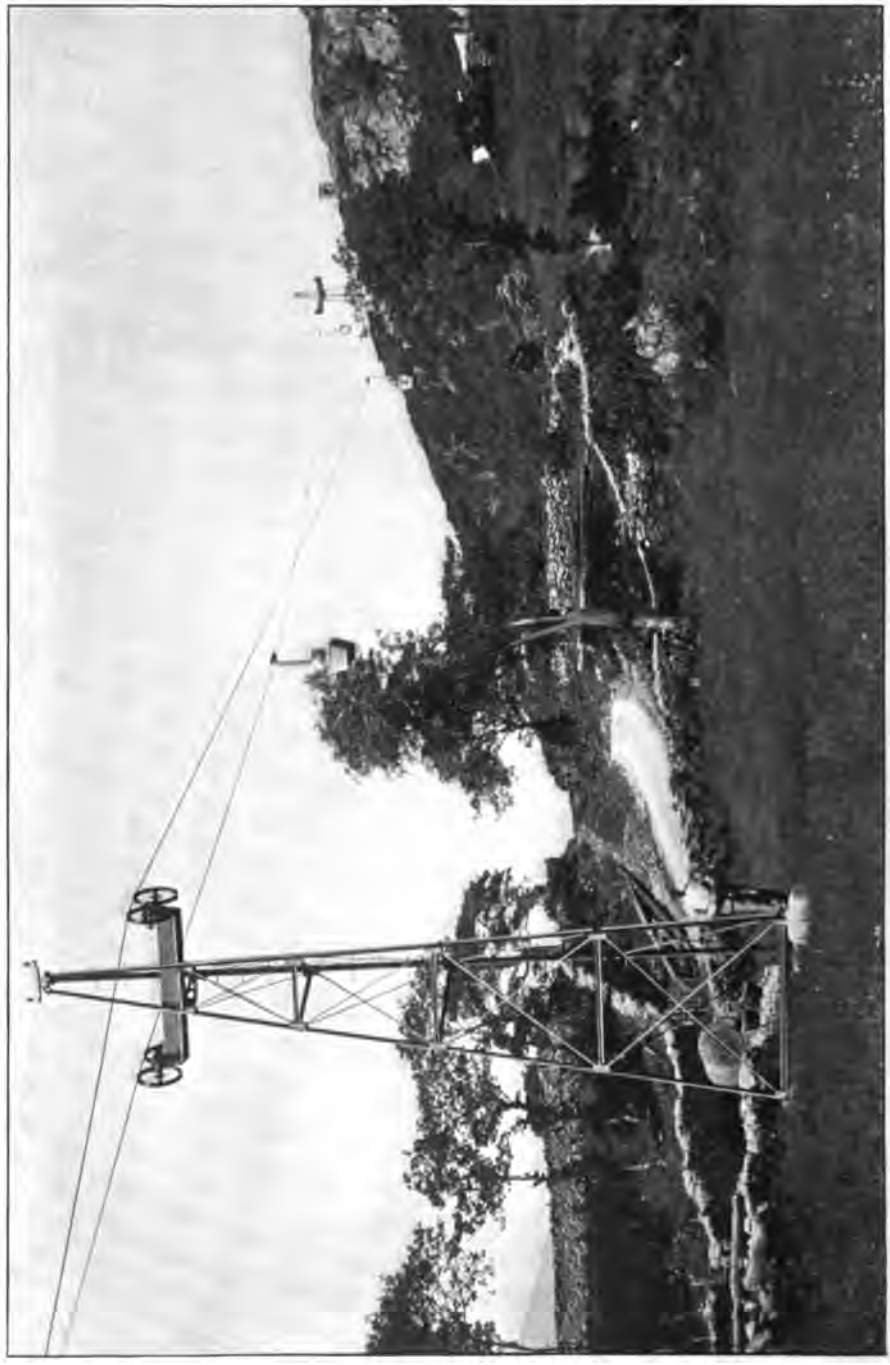
keep the particle afloat. Probably the air will also be separated. Some such explanation does at least afford a satisfactory reason why the particles of ore travel out of the oil and through the wall of water round the bowl and lodge themselves against the outer circumference of this.

In the oil-mixing cylinders the agitation is performed by plates and vanes attached to the interior surface of the revolving cylinders. The pulp enters at one end and oil is dropped in at any suitable point that will ensure a sufficient quantity of ore being taken up. The pulp from the first cylinder is collected by a Spitzkasten and passed to a second cylinder where it is agitated with a second lot of oil, and then again to a third cylinder. The oil concentrates from each cylinder go forward together to the centrifugal. The concentrates are washed out of this into the second. The oil which flows away goes to a tank

ONE OF THE WATER WHEELS AT ST. DAVID'S

whence the water is syphoned away below and the oil flows off above, to be sent round to the mixers. Very little oil is lost, and there is no loss of ore in the oil, for even if not perfectly "whizzed" free of ore, any particles remaining would but circulate a second time round the cycle without loss. The best oil appears to be the residuals after distillation of the light burning and lubricating oil.

At the Glassdyr copper mines near Dolgelley an ordinary vanner concentration plant recovered only 14.5 per cent. of the metallic contents, valued at 4s. 7d. per ton of ore treated. The cost of doing this was nearly 6s. per ton. The oil system recovered over 80 per cent., worth 30s. 9d., at less cost, and later progress has shown 90 per cent. recovery. The percentage of recovery is dependent to some extent upon the fineness of reduction of the ore, with consequent more perfect liberation of



THE ROPEWAY FOR THE ST. DAVID'S MINE, INSTALLED BY THE ROPEWAYS SYNDICATE, LTD., LONDON

the metallic particles. Any metallic particle enclosed by silica becomes lost. Reduce the silica to a less size and the metallic stuff is set free. The commercial value of finer pulverisation will, of course, depend upon the increased recovery equated with the cost of grinding small.

An easy experiment to demonstrate the action of oil can be made by mixing common sand with graphite, which acts like a sulphide ore and sticks to oil. If this be placed in a bottle three parts full of water, some thick mineral oil be then run in, and the bottle be shaken up, the graphite will be taken up by the oil, and the sand, now clean, will fall to the bottom of the bottle. Such is the oil concentration process, but it would be a failure were it not for the centrifugal separator that has so far proved to be the only means of ridding the ore of the tenacious oil and saving the latter for use over and over again. Blende is, perhaps, the chief exception among sulphide ores to the rule of oil concentration. With this ore the removal by oil is not complete. On the other side, oxide of copper and cassiterite (tin), though oxides, can be partially recovered by oil.

Having seen this much of Welsh gold, the question comes naturally to mind as to the origin of all this activity. The mine which supplies the gold-bearing quartz is up the hillside, about three-quarters of a mile distant. It may be found by following the wire rope tramway, put up by the Ropeways Syndicate, Ltd., of London, and capable of bringing down 250 tons of ore daily. The line is about 1450 yards long, and has a capacity of twenty-five tons per hour, —an amount that may be considerably increased, if necessary, by running above the normal speed. The actual difference in altitude between the two terminal points is about 300 feet, this giving a mean gradient of about 1 in 15. In the course of the above distance there are only ten trestles of moderate height, and, though the ground does not lend itself to spans of very great length, two of them are nearly 500 feet long. Each bucket carries a load of 6 cwt., and the speed is controlled automatically by a

ONE OF THE ROPEWAY TERMINALS

EMPTYING ORE BUCKETS AT A ROPEWAY TERMINAL

water regulator. Mr. J. Pearce Roe, of the Ropeways Syndicate, Ltd., designed the line, and it was erected under the supervision of Mr. H. Roe. This tramway is very well shown in the illustration on page 504.

The ropeway commences near the mouth of the main adit, whence issue trucks of ore which are tipped to a shoot from which the swinging buckets of the tramway are filled. As the mine is above the mill, only a brake is required to regulate the speed, the full descending buckets supplying all necessary motive power. The lode is parallel with the bedding planes of the upturned rocks, so that it may be either a fissure or a separation lode. The adit follows the lode into the hillside. Within are shafts, down to lower levels, the deepest of which is now 700 feet from the highest point in the mine. A series of galleries is driven in the lode and the ore is got at various points by stoping and

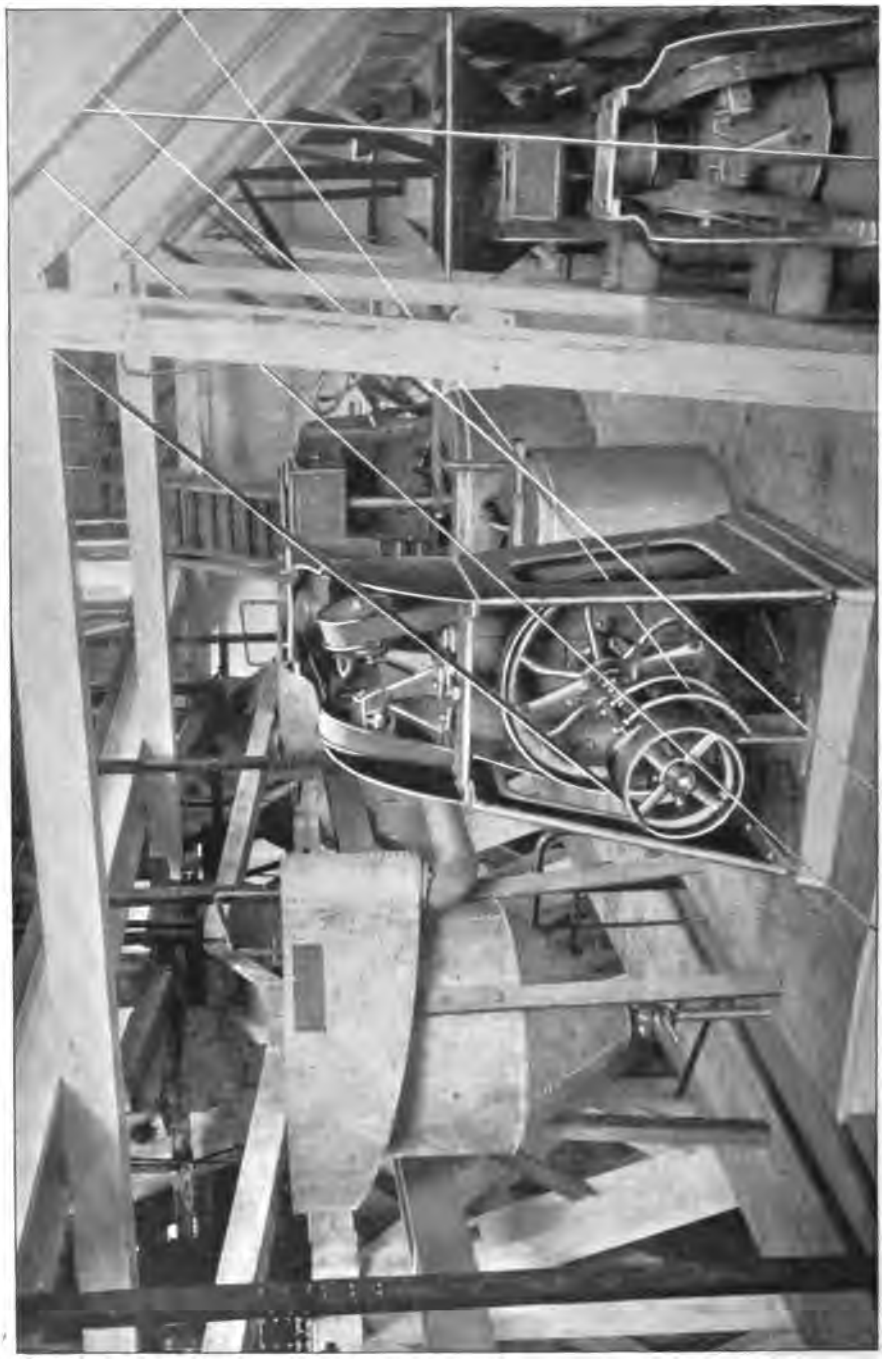
is sent down shoots to the tram adit. Thus, after once loading into a truck, the ore is not handled again, but passes forward to the stamp mill and tailings plant by mechanical means alone.

In the mine, the lower workings are provided with a winding gear, worked by a Tanyge oil engine. An air-driven pump is used to dry the lower levels, which, however, will soon be drained through the new adit at a lower level than the main adit, and, in time, Mr. Wright hopes to extend the workings even to 2000 feet below the top of the hill, where the shaft comes out to grass and serves as a convenient entry for miners in the upper galleries. As the lode averages a convenient width for adits, there is not much surplus rock to be removed, and, as the dip is so nearly vertical, there are no hanging wall troubles to deal with at St. David's, and but little timbering is required, an occasional strut or horizontal pillar of poor rock being left in, while parts of the worked-out lode are used as a receptacle for waste rock, thus saving the cost of bringing this to grass, and affording support between the two walls of the mine. There are 7000 feet of levels in this mine, and 2000 feet of winzes and shafts. The lode runs from a few inches to as much as 10 or even 20 feet in width, averaging about 5 feet, as a general rule.

The ores, whether of copper, lead, or zinc, are all sulphides, the gold being free, and some specimens are very rich in the pure metal. The diagram on page 493 shows the mine in vertical section along the lode. Across the lode a mine like this is simply a narrow, nearly vertical, cleft in the hill, and the art of mining such a lode is to remove the whole of the payable ore which fills the huge vertical fissure, if it be a fissure. Clearly, in a height of hundreds of feet many horizontal galleries must be run from which that part of the lode immediately above the gallery must be removed by the operation of stoping, access to the stopes being by ladders from the gallery.

As regards output, five heads of stamps will crush 15 tons of ore per day of twenty-four hours, the whole battery

THE ELMORE ORE CONCENTRATION PLANT AT ST. DAVID'S, INSTALLED BY THE ORE CONCENTRATION SYNDICATE, LTD., LONDON



ANOTHER VIEW OF THE ELMORE ORE CONCENTRATION PLANT AT ST. DAVID'S

thus dealing with 150 tons per day, which must be yielded by the mine if the battery is to be kept in full work. Ore is got by means of compressed air rock drills which drill holes to a depth of about 5 feet in the working face. In each hole are placed one to six dynamite cartridges, and each explosion brings down from five to six hundredweight of quartz. The firing of a shot in a mine sets the air in the galleries into vibration, as though the gallery were a long organ pipe, extinguishing lights and giving, in addition to the sharp report of the explosion, a low note, which is very startling, as it comes unexpectedly.

The excellence of the whole mechanical plant and the business-like methods of management, both in the mine and in the mill, make it easy to understand that, where gold is coming forward as seen at St. David's, the failures of the past have been in men and methods. In most of the Welsh fiascos it was not the mines that were bad; it was the methods. Extravagant buildings, heavy expenditure on unsuitable machinery, and a class of management perhaps better able to spend gold than to save it, contributed to render past efforts a mere speculative gamble.

In one instance, to give an illustration, it was only after three attempts to carry water round a hill that the water could be induced to flow. The first two conduits had been constructed on the basis of water flowing up hill. In this and similarly stupid errors thousands of pounds have been squandered. In this case, when finally obtained, the water was useless, for there was no mine in existence.

At another mine a ten-head stamp battery was put down complete with power, rock drills, compressor plant, and manager's house, all of the best. Long levels were driven, all capital was spent, and good, payable rock was found; but not a stamp was dropped, and the whole was sold by auction for a song.

This was the Voel mine. It is now in good bands and is being actively worked. The manager, Mr. H. J. Carnegie Williams, took the writer through a large extent of the workings which had been almost entirely executed during the twenty months preceding the writer's visit.

At this mine there are several lodes which run approximately parallel with the face of the hill, and have a dip of 75° to 90° to the south-east. They are reached by cross-cuts at half a dozen levels, and already about 30,000 tons of good, rich ore have been made ready for the mill. The ore found is chiefly galena and blende, with some copper, silver, and a little gold. It is to be treated by concentration, and the plant was nearly ready to start work at the rate of ten tons per hour, though the company commenced operations only in October, 1900. The ore brought from the mine is run in trucks to the bins and passed through stone breakers and then through sizing trommels which sort out the large stuff. This passes to crushers and then to a second trommel, which sorts out everything over 5 mm. size.

All the crushed material is sorted by trommel to sizes of 5, 4, 3 and 2½ mm., and then passes direct to jigs. Hydraulic classifiers await the final particles and supply the jigs having 2 and 1 mm. screens.

Each jig is divided into five compartments, with an appropriate perforated bottom to pass the above sizes, and is covered with a layer of varying thickness composed of specially broken and sized Belgian iron slag. The jig boxes have wooden plungers, moved up and down by variable eccentrics from eighty to ninety-six times per minute from one inch to two inches, depending upon the size of the ore and other factors.

The pumping effect of the plungers loosens the slag bed and the heavier particles of ore penetrate to the grid and are sucked through to the hutch beneath, whence they are let down to a box below, ready for sale. The lighter portions pass gradually forward to the next box over the top of a division plate, and so on. In each box the heavier ore passes down and away to the hutch below, and, in this way, the metals are separated and concentrated, the final remainder being rejected. Though 5 mm. has been selected as a probable

THE STAMP BATTERY AT GWYN-FYNYDD, INSTALLED BY THE SANDYCROFT FOUNDRY COMPANY, LTD., CHESTER, ENGLAND

maximum size, it may occur that the middlings still contain metal particles. If so, these would be reduced to 3 mm. and jigged in the third line of boxes.

There are in all five compartment jigs, divided into two lines, each of 5, 4, 3½, 3, 2, and 1 mm. jigs, and one line of 3½, 3, 2, and 1 mm. The stuff smaller than 1 mm. is run with water down a sloping trough, in the course of which are a series of hydraulic classifiers, or Spitzkasten, with gradually increasing width of mouth from 9 inches to 7 feet. These classifiers catch successively smaller and smaller particles of material, the ore and heavy particles gravitating out of the running stream. The particles thus classified fall upon a series of

vanner tables which have variable end and lateral throw, on which, starting from the entry corner, the sized particles arrange themselves according to gravity in distinct curves of lead, zinc, or other ores of different specific gravities. These are so clearly marked that, when they arrive at the discharge end of the table, each different ore can be caught in its own box by simply adjusting the division plates. Separation by gravity and washing, as described, can be accomplished only where preliminary sizing is done, for a piece of light material of large size gravitates through water as fast as a heavier piece of small size. Hence, the use, first of sizing trommels, then of gravity, on particles of nearly equal size.

In order to make the jigging and vanning as perfect as possible all this machinery is driven by a gas engine of 50 H. P., while the heavier machinery is driven by an independent engine of 75 H. P. The power house is at one side of the mill, the producer gas plant being by Tangyes, who also supplied the gas engines. The jigs and tables, stone breakers, crushing rolls and trommels were supplied by Messrs. George Green & Co., of Aberystwith. The compound air compressor and compound steam engine to drive sixteen rock drills was supplied by the Tuckingmill Foundry Company, who also furnished the rock drills. The whole dressing plant is constructed on the steeply sloping hillside so that stuff gravitates forward. The concrete floors all slope slightly to drain, and finally the tailings of clean, sharp quartz are pumped to a piece of ground, at a distance from the mill, to be made into flagstones by admixture with cement under hydraulic pressure.

The Voel mine has been well and fully developed, and enough ore has been taken out to run the mill twelve or eighteen months at the rate of 100 tons of ore per day, and a better or more complete concentration plant it would be difficult to find. The number of men at the mine and erecting machinery was 140, but this number would be reduced considerably on completion of the concentrating plant, the ore being dealt with as automatically as possible, and everything being designed with a view to stability and economy of operation.

The workings so far consist of about 2388 feet of levels, 2401 feet of cross cuts, 1149 feet of shafts, winzes and rises, with 1151 feet of old workings timbered and cleared. The highest level is 1000 feet above sea level and the main shaft is down 190 feet below sea level.

The compressor house is some distance from the mill, and air is carried round to the mine by pipes, with a second large air receiver at a considerable distance from the compressor. This helps to maintain the pressure at the more distant points and equalises the flow of air in the pipes.

The third of the mines investigated in course of this enquiry, which grew in importance and surprises at each step, was the mine known as Gwyn-Fynydd, about seven miles further up the Mawddach. The Gwyn is a gold mine more particularly, under the management of Mr. H. J. Nicholls. As at the St. David's mine, the mill stands in a narrow, rocky gorge where the peat-stained Mawddach takes a leap of 60 feet and supplies power sufficient to run the mill for nine months of the year, a steam plant, by Messrs. Fraser & Chalmers, Ltd., of Erith, Kent, standing by for the drier period. Here there are forty heads of modern rotary stamps dropping 7 inches at eighty-five times per minute and set in the order 1, 3, 5, 2, 4. They were supplied by the Sandycroft Foundry Company, Ltd., of Chester. The general arrangements are very similar to those at St. David's, the ore from the mine, about 500 yards away, being dumped over grizzlies direct to the stamp bins or to the crushers, and fed by the same vibratory circular revolving plates to the mill. There is no tailings treatment here. Any particularly rich stuff and the clean-up of the stamp boxes is treated in amalgamating pans. Each stamp head will deal with about two tons per day.

The air compressor, of single-cylinder type, in a building near the mill, is

driven by a turbine to which water is piped from a point about half a mile away at a head of 170 feet. Failing water, there is a steam engine as a reserve.

The Gwyn mine has been well developed. It contains 9000 feet of levels, 3000 feet of winzes, and 450 feet of shafts. The greatest depth of working is 650 feet, and some very rich stone is met with from time to time.

Obviously Welsh gold is far more important than the place assigned to it in the geological survey maps, which have not been re-edited since 1855, and carry only a single reference to the existence of gold in the area treated of. This is marked by the Gwyn-Fynydd only, though copper is freely indicated throughout the area.

There are other mines that might be named, but already the subject has expanded beyond the original intention. Suffice it to say that Welsh gold mining is no myth, but a paying reality, and has proved, on investigation, to be carried out on sound lines both in the science of mining and the art of treating ores, while, as regards the mechanical details of the machinery employed and the care of the installations, there are probably no better plants to be found.

The writer is indebted to Mr. H. J. Wright, of St. David's mine; to Mr. H. J. Carnegie Williams, of the Voel mine, and to Mr. H. J. Nicholls, of the Gwyn-Fynydd mine, for kind help in preparing this sketch and affording every assistance and facility for seeing as much as possible in a brief visit. It is scarcely necessary to add that the important accessory to a successful mine, viz., a well-equipped laboratory, is to be found at each mine. The writer is also indebted to Mr. Godfrey C. Isaacs, the managing director of the Development Company, for kind permission to visit the mines and plant.

THE FUTURE OF THE IRON AND STEEL TRADES

SOLVING THE LABOUR PROBLEM

By Axel Sahlin

Mr. Sahlin's wide experience in the iron and steel trades on both sides of the Atlantic has enabled him to write with an intimate knowledge of the several phases of his subject. He is a member of the firm of consulting engineers, Julian Kennedy, Sahlin & Co., of London, and general superintendent of the Millom and Askam Hematite Iron Company, Ltd., of Millom, Cumberland. He graduated from the Technical University at Stockholm, Sweden, and worked for a time at Krupp's. Later he was assistant engineer to the Cambria Steel Company, chief engineer of the Pottstown Iron Company, superintendent of the Maryland Steel Company, at Sparrow's Point, and consulting engineer of the Brown Hoisting Machinery Company, of Cleveland, Ohio, U. S. A. He was also a member of the Commission of the British Iron Trade Association which visited the United States last summer and reported at length upon the American iron, steel and allied industries.—THE EDITOR.

DEALING in futures is risky, and yet all human activity is based on futures, on hope of coming developments, coming results, coming rewards. In whatever we undertake we draw heavily on the future. A few thoughts on the future of our fundamental industry may, therefore, be permissible. The iron industry is fundamental, because without iron progress and civilisation would have been impossible, and because no substitute for iron has yet been found, nor is it likely ever to be found.

Edward Atkinson, the well-known statistician, predicted twenty years ago that in the year 1900 the United States would produce and consume 15,000,000 tons of iron and steel, and he was duly ridiculed. His prediction, however, came true. The 15,000,000 tons were made and consumed, but did not quite fill the want. During the coming year something like 8,000,000 tons of blast furnace capacity, nearly as much as the entire yearly production of Great Britain or Germany, will be made ready for operation in the United States; this will leave only 2,000,000 tons of additional capacity to be constructed in the seven years to come to verify Mr. Atkinson's next prediction that in 1910 the United States will require 25,000,000 tons of iron. Even more rapidly has the rate of production increased in Russia, while progress in Germany and Austria is also considerable. In Great Britain the expansion, of late, has been arrested; but indications of renewed activity, both in the mother country and in the colonies, are not lacking.

New railway systems must be laid out to cover large territories now being opened up to civilisation on all the continents, wide ramifications of electric tramways must supplement the railway systems already in existence, steel cars must take the place of the antiquated wooden trucks. Freight steamers, designed for rapid and economical handling of cargo, must be built to replace the now common type of slow and unwieldy ocean tramps. All this must be done within a few years, and for all of it iron will be required. Besides, there are continuously springing into existence new lines of manufacture, such as, for instance, the motor car industry, the steel-frame building, the barbed wire fence, and the wire nail of the past, and who knows for what purpose in the future. The rapid growth of the industry can, therefore, be taken as an axiom.

As the demand and production of iron grows the available ore reserves will be

VANDERGRIFT, NEAR PITTSBURGH, THE WORKINGMEN'S TOWN, BUILT

diminished, and the time will come when the now known sources of supply will give out. This, however, we need not concern ourselves about. Only two of the six continents have been explored for iron ore, and that only partially. Many deposits of enormous extent, but of no present commercial importance, are known, and others are yearly being discovered. Methods for eliminating impurities are also being evolved. These will enable us to utilise deposits of mineral previously valueless.

The phosphoric ore beds of Lorraine and Luxembourg, of Styria, of Central and Northern Sweden, of Lake Superior and Alabama, taken as examples, possessed but little commercial value until the invention of the basic steel process made them the principal ore supply of our generation. Let the time come when we have learned to treat titanium in the iron furnace and other enormous mines will be available. We may also confidently expect that improved separating processes will help us to economically utilise practically inexhaustible strata of low-grade ore now too expensive to reduce. We can, therefore, assume that the ore supply will prove sufficient for many centuries of greatly increased production.

The fuel supply is more limited, but even in regard to this the statement that only two out of the six continents have hitherto been partially searched for coking coal holds good, and while it is obvious that oxide of iron will continue to be the only raw material from which the metal will be produced, it is far from certain that coke, coal, and charcoal will be permanently employed as the sole smelting and reducing agents in the manufacture of iron. New methods may possibly come to the front which will reduce the present wasteful employment of energy stored in coal seams and forests. Electricity, terrestrial magnetism,

FOR ITS OPERATIVES BY THE AMERICAN SHEET STEEL COMPANY

solar heat, the ocean tides, the winds, water-powers hitherto so greatly neglected, offer possibilities of which some are likely to be employed by coming generations in order to aid and replace the ever scarcer and more precious carbonaceous fuel.

This, however, carries us far into the future. For several generations to come we are likely to make more and more exacting demands on coal reserves. To the fuel-producing districts the industry will, therefore, be attracted, and as fuel in one region becomes exhausted, the iron works will leave it for more suitable locations. We have learned to transport ore at a very low cost. Fuel is more difficult and expensive to handle, and is, moreover, required for all the subsequent manufacturing processes and industries for which the iron forms the raw material. Fuel,—cheap and abundant fuel,—is, therefore, a first necessity of the iron industry of the future, as in the past, and the want of it is the only real limit for the expansion of the industry.

The human factor is the one which, in the future, will be the prime cause of changes. The status of labour, the political relations of nations, and of each to its citizens, the influence of more general education, of the advance of science and of new inventions and methods are going to work changes the extent of which we cannot now even conjecture. All we have to guide us in speculations as to the future are the phenomena of the past and of the present, and the conclusions which we may be able to draw from them.

In regard to manufacturing plant, the principles of saving heat, transport and handling, waste and intermediate profits will gradually result in bringing together all the furnaces, mills, and factories which serve to carry forward the conversion of ore into finished product,

STREET VIEWS AND HOUSES AT VANDERGRIFT

ready for the consumer, under one management and in the most suitable location. This location will, except under special conditions, be found near the fuel and market. The heat imparted to the ore in the blast furnace will not be permitted to be lost before the finished rail, plate, wire rod, or whatever may be the final product, is ready for shipment. Combinations will multiply which will be able to hand over to their customers a complete battleship ready for action, in which every pound of iron and steel has been made and finished

from their own ore and in their own shops. What the evolution of methods will be, what inventive genius will create in the way of new machinery and appliances, what chemical reactions will be discovered and made to serve the metallurgist in obtaining a cheaper and better product, only those will know who will live to see. More and more brains and education are yearly brought to bear on these problems, and though the result has been great in the past, it will be greater in the future.

In the spirit of the times there is a marked tendency towards concentration, centralisation, consolidation, and combination of interests. Amongst the governments of nations this spirit shows itself by an insatiable land hunger, and in the absorption of weak or badly governed neighbours; in the strengthening of armies and navies; by the State demanding of its citizens the ability and readiness to defend their land and their nationality; and also by the slowly awakening sense of the obligations which governments have towards the tired workers and towards the crippled and submerged members of their constituencies.

Yet more forcibly and strongly does the tendency show itself in industrial life. The gigantic forces which science and discovery have liberated and placed at the disposal of industry require new and greater means for their control and utilisation. The mechanic working at his trade, surrounded by journeymen and apprentices, gave way two generations ago to the industrial workshop or factory producing a varied product, but working independently and under ever-growing competition. Recently this competition has become so keen that the system has proven inadequate, except for specialities, and the shop is being merged in a combination of shops or companies, which, in extreme cases, reaches the proportion of a trust or an industrial monopoly.

This development is quite logical and forms only a link in the chain of evolution which some day must incorporate us in a socialistic system the practical organisation of which nobody has yet succeeded in formulating, but which, with fair degree of certainty, we can foresee coming,—a solidarity and co-operation of all the members of the State or the political community for the good of all, a society where the master's interest will actually be that of the worker and the worker's interest that of the master.

But we are not yet prepared for such a change. We have still to fight many industrial battles, to witness many acts of over-reaching tyranny, of wanton destructiveness, of vicious carelessness and indifference, before the outrageous waste of brains, energy and capital of the present industrial system can be stopped or turned into profitable channels for the benefit of leaders and workers of their community, their nation, and, in the last instance, of humanity.

To work for a nearer approach to this utopian state is the alleged object of the anarchistic and socialistic propaganda, and also of labour and trade unions,—misshapen creations seeking to promote equality by levelling all to the standard of mediocrity or inferiority, and presuming to regulate and guide their industry. They do not know how, and, therefore, defeat the admirable purpose which ostensibly stands at the head of their programme.

In the iron trade more than in any other branch of business changes along the lines indicated above are clearly discernible, and the strides taken and being taken during this generation have been so rapid and so long as to place these changes within the perspective of our personal experience.

It has been the fate of the writer to cover during the past five years, as a manufacturing engineer, investigator or promoter, a large part of the industrial territory of iron and steel from Southern Spain to the north of Russia, from Scandinavia to the Alps, as well as from Canada to the Mexican Gulf, and from the Mississippi to the Atlantic. Personal observations, therefore, enable him to assert that within this enormous territory a rapid and constant change and evolution are taking place.

The United States have seen the single works merged into groups, and these

THE VILLAGE OF ALTENHOF, FOR RETIRED AND DISABLED WORKINGMEN OF THE KRUPP WORKS

groups swallowed up by corporations which extend their influence over the entire country and beyond its boundaries. Such are, for instance, the United States Steel Corporation, the American Bridge Company, the American Locomotive Company, the American Car & Foundry Company, the American Shipbuilding Company, and, oldest and most successful of them all, the Standard Oil Company, not to mention many others.

In Germany the Rhenish Westphalian and other syndicates have demonstrated the possibility for a sales combine to successfully and permanently regulate and dispose of the product of its constituents. In Austria the Wittgenstein group of interests affords a most striking example of an intelligently, liberally and wisely conducted industrial combination. In Russia negotiations have for some time been in progress for the consolidation of the southern iron plants.

In Great Britain the Welsh works are joining interests under the leadership of Arthur Keen. Germany years ago merged its railways, which, in the hands of warring companies, inadequately served the industry and the public, into the admirably managed State-owned combination known as the "Preussische Staatsbahnen." The Pennsylvania Railroad, in the United States, with its tributary systems and ramifications, controls to-day, directly or indirectly, 24,000 miles of track, as compared with a total of 23,000 miles for all the railways of Great Britain and Ireland. The Atlantic steamship lines have ceased their strife and joined hands. Everywhere we see the same effort to reduce waste and to gain strength by co-operation instead of by competition. The device in the coat of arms of the Belgians, "C'est l'union qui fait la force," is verily becoming the motto of the industrial world.

THE KAISERIN AUGUSTE-VICTORIA HOME AT ALTENHOF FOR CONVALESCENT WORKINGMEN

If the policy and methods of these combinations were to keep up prices, to curtail production, to furnish inferior service, in a word, to tyrannise over the public, they would themselves seal their doom. But if their power be used to lower, and, above all, to equalise and regulate prices, to furnish improved service and products, to deal generously and fairly with their employees and customers, who can say that they are not a power for good? Take,

A SOCIAL CORNER AT ALTENHOF

for instance, the case of the Standard Oil Company, in the United States, —a corporation controlling untold millions and having a practical monopoly of the mineral oil trade of the world. Must we not acknowledge that we owe to its excellent methods of manufacture and distribution the cheap and good illuminating oil which to-day lights the cabin of the poorest peasant in the remotest corner of the world? Little does the city-bred man of Western Europe realise what a blessing and what a wonderful progress the humble kerosene lamp has brought. Has not the Standard Oil Company shared its profits with the public by steadily reducing prices, while at the same time

it accumulated unheard of wealth for itself? Were we ever made to understand that the employees of this world-wide organisation were badly paid, or inconsiderately treated? Has anyone ever heard of the Standard Oil Company having a strike on its hands?

Turning to the United States Steel Corporation, must not every thinking man recognise that during the past year the judicious regulation of the pressure of trade by Mr. Schwab and his associates has saved us from a short period of fabulous prices, followed presumably by a sudden collapse of even more disastrous proportions than those of the past?

By permitting the existence of combinations, like the Steel Corporation, the large railway companies, and other monopolies, the State has conferred on them a great privilege, and only as long as they recognise this by their methods of doing business is their existence justified. An error on the part of their leaders is always costly and reaches larger circles in proportion to the size of the monopoly. The mistake may be conceived to be so great as to force the State to revoke the privilege granted and eventually itself assume the management of an industry which, for the benefit of all, must be carried on in an equitable and sagacious manner. As it is human to err, situations may arise that such a reversion to the State of the properties gathered into a trust will be the only possible end of the combination.

A VERANDAH OF THE KAISERIN AUGUSTE VICTORIA HOME

It has been said that most of the trusts are over-capitalised. This may or may not be so, depending on the valuation

AN INDUSTRIAL COMMONWEALTH OF FIVE HUNDRED HOMES AT PORT SUNLIGHT, ENGLAND, CONNECTED WITH THE WORK OF MESSRS. LEVER BROS., LTD., SOAP MANUFACTURERS, OF BIRKENHEAD

of the raw materials which they control. But even granted that such be the case, and that the resources of a combination would fail to provide sufficient working capital and cover standing charges, this would be bad for the holders of the common stock, perhaps in extreme cases also for those who have invested in preferred shares; but the business would unquestionably be carried on by the bondholders to whom the property would revert under the drastic writing-down of values, carried into effect by the entire or partial wiping-out of the stock. The industry, however, need not be seriously or permanently affected by the change of owners.

It has been suggested that the constituent companies might again separate to renew the internecine war of competition of the past. This does not seem likely, or even possible, as under the organisation of a trust each department is organised and equipped to perform a specialised function, just as the foot or hand, the eye or the ear, each do their work for, and receive their living from, the central system of the body. Sever one member from the rest and it will become useless and die, as the body becomes crippled. So also would fare the properties which for some time have been members of a large organisation, and which have been designed or reconstructed to perform a special work or to produce certain articles.

To dismember an industrial combination without entire destruction of values would be found a far greater and infinitely more difficult task than was the bringing together of the properties, and would mean an international calamity so great that the State, when all else failed, would be forced to interfere and assume control. That this can successfully be done is shown by the example of the Prussian State Railways.

It is the railway combinations which more directly than any other serve the iron industry, as well as the public at large, and which, therefore, are most likely to become State institutions. Their privileges are great; so also are their obligations and duties. They must provide ever-increasing and fully adequate transportation facilities. They must always be ahead of the demand, so as to build up the country which they are permitted to serve; their rates must be made to aid the industries which depend on them, not only to exist, but to prosper and grow. When a railway

company, entering a large city, cannot give such service as to bring the population from the congested centre to the suburbs along its lines; when their freight rates are such as to deter manufacturers from establishing themselves in their territory or from extending their operations, then they are not performing their duty as implied by the immensely valuable privileges granted them.

A railway is largely responsible for the value of the real estate along its line, and as this grows, so grow the value and earning capacity of the road. If we see a railway company ignoring demands and improvements, eager to maintain rates without giving better or more liberal accommodation, disregarding the law which makes business, like water or electricity, flow along the lines of least resistance, then we can safely say that such a company has outlived its usefulness. It requires new men, a new system, new ideas; or if these cannot be found, a change of control which will insure the road being worked in the interest of the State and the public, even if it eventually has to be done by the State itself. The trusts, which are bound to grow in number and importance, will require, on the part of their leaders, extreme ability, broadness and sagacity in selecting their lieutenants. Men will be promoted young, worked hard, and retired early. The strain will be such as no man can endure during a long sequence of years, but the rewards will also be tempting, and as the responsibilities become greater and the climb higher, there will always be more room at the top, and fewer men fit to fill the posts. The coming captains of industry will do their life work while yet in possession of their entire youth, full of energy and self-reliance, tempered by many-sided training. Their aids will more and more specialise their work and their spheres, and must become past masters in their arts. Every man holding an important position must be educated to fill it and must give it his entire and undivided energy. Only thus will it be possible to build up staffs or organisations which will stand the strain and the demand made on them.

PORT SUNLIGHT COTTAGES. THREE SHILLINGS A WEEK

Capital is but a brief expression for "labour stored," or passive labour. As carbide of calcium bricks give off

A SPECIMEN OF INSANITARY PROPERTY ORIGINALLY ON PART OF THE PORT SUNLIGHT ESTATE

acetylene gas when placed in water, so will capital, when expended, call forth active labour.

The two together,—labour and capital,—perform what work is done in the world. The one cannot exist without the other. This law is so evident, so simple, and so generally recognised in the abstract, that it is remarkable to see how persistently it is ignored in practice by both the interested parties.

The industrial labour class is a modern institution. Before the days of the industrial workshop the journeyman was often a member of the master's household. A bond of personal acquaintance and interest bound the two together. The worker and the employer did not represent separate classes; on the contrary, the worker confidently looked forward to the day when he himself would become a master and employ labour.

The factory system rudely destroyed this relationship and brought in its place the hard, cruel law of supply and demand. This introduced amongst the working classes a bitter, antagonistic feeling toward their employers. Neglected and oppressed, with no education, low wages, and, only too often, poor and insufficient food and unwholesome dwellings, it was no wonder that the workmen were driven into organised opposition to the employers, which yet exists and grows, though the grievances which originally justified it have been relieved to a great extent. The workmen of one or two generations ago were, indeed, more sinned against than sinning, and if, when they discovered their strength, they went too far in the use of it, this was greatly the fault of the employers and of the governments which had done so little for their enlightenment and happiness.

The present condition of antagonism is ruinously expensive to both capital and labour. It must be changed, and with it the whole aspect of the industrial system. Three forces must co-operate in bringing about the change,—the governments; the employers, be they individuals or corporations; and especially the workmen themselves.

The State or government must aid by

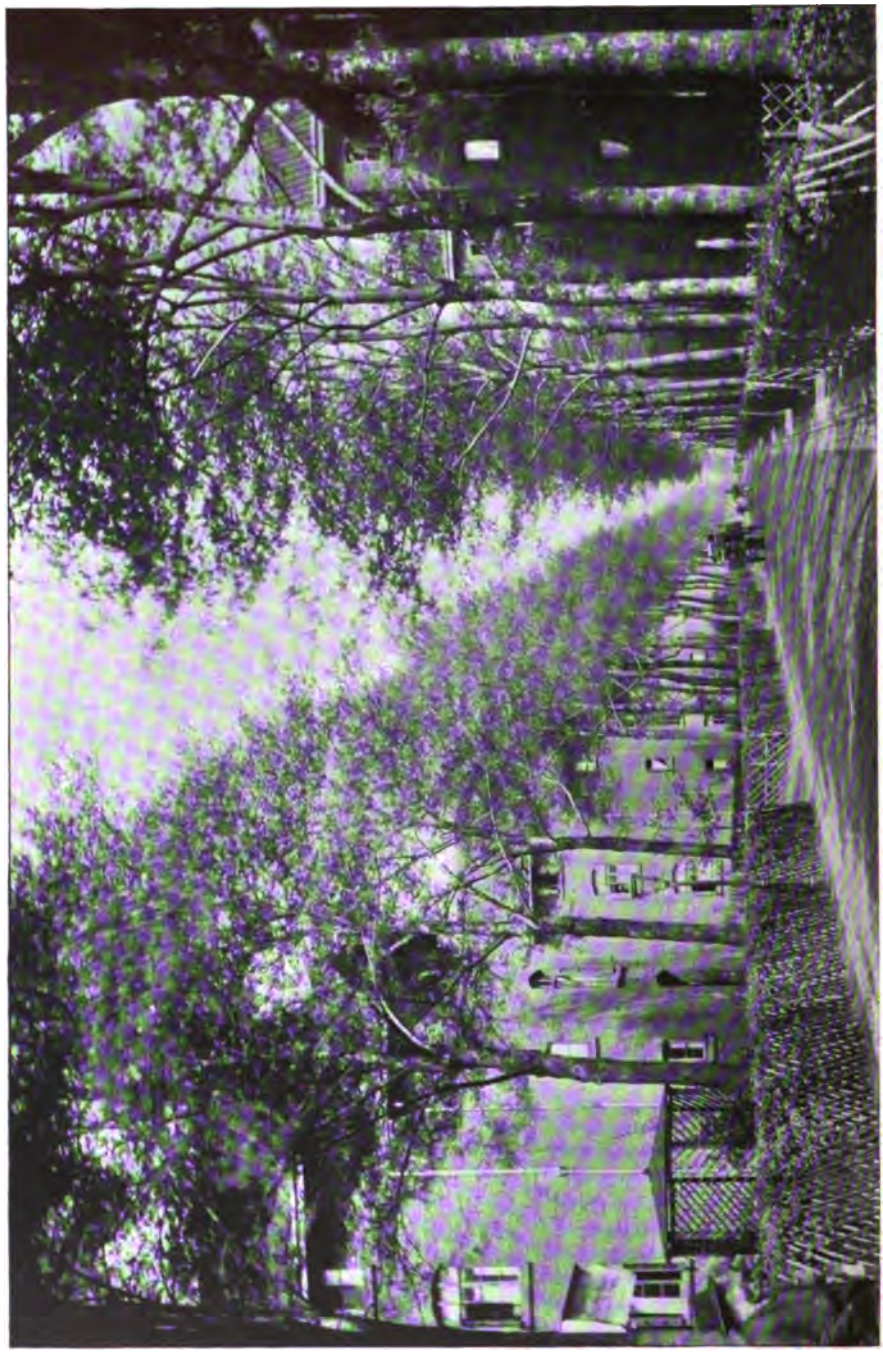
NEW WORKMEN'S COTTAGES ON THE SAME SITE AS THE INSANITARY PROPERTY SHOWN OPPOSITE

taking care of the very young and of the aged. It must provide really good schools where the children will be trained to think and reason, as well as taught that, if they have rights, they have also duties.

It must also make some adequate provision by which the labourer, whose wage in all climes is just about as much as he requires to keep body and soul together, can look forward to old age without the background of the poorhouse. A life of work, be it ever so humble, deserves an old age with rest without humiliation or privation. Steps will unquestionably, in a not very distant future, be taken to introduce old-age pensions in all civilised countries. Germany is now making experiments with such on a very large, though hardly adequate, scale.

As regards the often unavoidable accidents with their train of death and disablement, the British Government has shown us an excellent method to deal with them through the Accident Law now in operation, making a compensation due to the injured or to those dependent on the deceased, no matter what the cause or whose the responsibility for the accident. This law is yearly relieving thousands of what without it would be pitiful cases of distress, and the onus which it lays on the employers is so light that it is hardly felt, as they protect themselves by insuring their entire labour force at a reasonable rate, which nevertheless indemnifies the insurance companies for the average risk taken.

"Am I my brother's keeper?" asks Cain in the dawn of the world. Since then humanity has ever been considering this pertinent question, "Are we the keepers of our brothers?" Let the employers of labour in the future make it clear to themselves that they, through their position and privileges, particularly are the keepers of their brothers, and that the workers who, year in and year out, spend their days in the shops, really are their brothers; that they were born into this world with the same gifts, the same capacity, and the same common instincts as the employers themselves, and that only fate and different opportunities may have developed them differently.



A STREET IN CRONENBERG, ONE OF THE KRUPP WORKINGMEN'S COLONIES

Let the employers also remember that what benefits and elevates the workers will, in the long run, accrue to their own advantage, and that it is impossible to work well without a light heart and without hope; that it is not charity which is needed, but means and training for the masses to help themselves, and treatment which will make each individual feel that he is considered and respected as a man. Do not expect that even this treatment or the most well-meant efforts will be sufficient to at once allay the bitterness and suspiciousness towards the more fortunate which, from childhood, are grafted into the labourer's mind. This would be too much to expect. But be sure that with better treatment gradually, almost against the man's desire, the conviction will come that he enjoys advantages which he perhaps would not get in other places and which are of value to him. Thus an unconscious loyalty, actuated by self-interest, will gradually take possession of the man, making him a better workman, a better citizen, and a better husband and father.

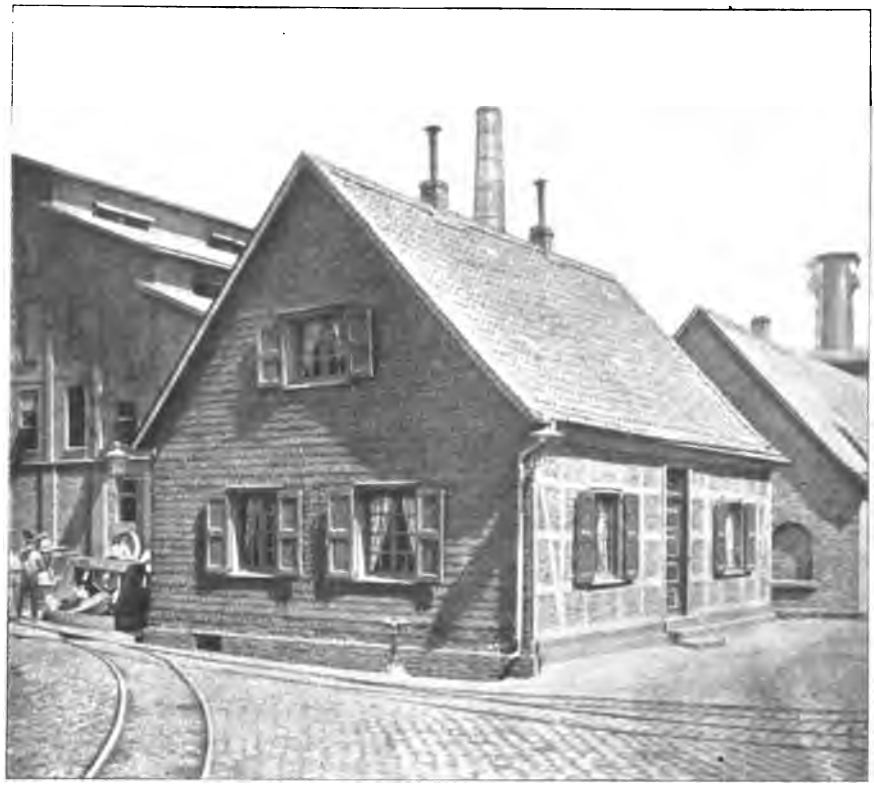
In short, give your workmen encouragement and hope of improving his position and you will have done much to solve the labour problem. Better education, ambition awakened by opportunity, good wages, and encouragement to save, better food, due to better training of the women of the working classes, better houses, attainable with the advent of the suburban electric railways, will gradually develop men, no longer slaves of either a greedy or short-sighted employer or of a despotic union. This is not theorising, but a statement based on facts.

One of the first of the great employers of labour to demonstrate these facts was the firm of Friedrich Krupp, the world-famed steel makers, of Essen, Germany. Their unrivalled success in producing war material early assured them an enormous profit, part of which they systematically have spent for the benefit of their employees. Their engineers are engaged for long periods, at yearly increasing salaries. No man, once given a fixed engagement, is discharged except for good cause. The old and disabled are pensioned.

Towns, of several of which illustrations are herewith given, have been laid out, with streets lined by comfortable and well-lighted workmen's homes, with boarding houses for the unmarried men, with assembly room, restaurants, Bierhallen,—so dear and necessary for the German comfort,—gymnasiums, hospitals, and baths. Special care has been given to the so-called "Consumverein,"—a large department store where necessities and luxuries can be bought for cash only, at fair prices, only by Krupp employees. The profit realised is yearly divided *pro rata* amongst them, according to the amount of purchases credited to each during the year. The positions in the sales department are, by preference, given to needy widows and daughters of old employees of the firm.

For the retired and disabled a special village,—Altenhof,—has been built, more remote from the smoke and din of the works, where the tired worker may age, free from care or want of the necessaries of life, where every street of neat cottages, every well-kept garden, every shady plantation speaks to them of the recognition of their late employers,—"Well done, thou faithful servant."

In order not to make the acceptance of these benefits a matter of charity, the firm compels their workmen to make regular contributions to the funds for the institutions during the years of their activity. About twenty-five years ago, when the writer, as a boy, was working at Essen for a short period, the photograph from which the illustration in the next page is reproduced was given to him and has ever since been preserved as a valued reminder of the deep impression then received by him of the far-sightedness, wisdom, and philanthropy of the Krupps. The lines written below the picture of the little cottage which yet stands undisturbed in the midst of the huge factory buildings of the Essen works are in the handwriting of Alfred Krupp, son of the original Friedrich Krupp, the founder of the firm, and father of the very recently deceased



THE OLD KRUPP HOMESTEAD AT ESSEN, GERMANY, STANDS SURROUNDED BY THE HUGE FACTORY BUILDINGS

head of the large establishments. They read:—

Fifty years ago this cottage was the home of my parents. May none of our workmen have to go through the struggle which the building-up of these works has cost us. The success which now so splendidly has rewarded our faith, our anxiety, and our efforts was doubtful during twenty-five long years. Let this example serve as an encouragement to others in difficulties. May it increase the respect for the many small homes and the great sorrows which often dwell in them.

The object of work must be mutual welfare: then work is blessed, then work is prayer.

May all, from the highest to the lowest amongst us, work with the same earnestness to found and secure his own future success. That is my greatest wish.

ESSEN, February, 1873.

Twenty-five years after my assuming charge.

ALFRED KRUPP.

With such a spirit and such an attitude on the part of the employer there is not, and there cannot be, any labour question. Every man who is worthy to be retained will, in his own interests, so perform his duties as to make his position and the many benefits accruing from it secure.

The only criticism which one might venture to make on the system is, that it is somewhat too paternal, and that the regulations may be too minute and too many to suit races not German, and that it lacks something of the elasticity necessary to obtain the greatest individual efficiency and effort from those for whose benefit it has been formed.

Another successful example of an employer's generosity and good-will is offered by the town of Port Sunlight, near Liverpool, built and owned by Messrs. Lever Brothers, of the Sunlight Soap Company. This successful firm pays 5 per cent. interest on £2,000,000 of preferred stock, and for several years past has paid 15 per cent. on its ordinary capital, of which £1,195,000 have been paid up. The firm builds small, but well-constructed, houses, and maintains a model town for its employees. Rent

is charged,—not according to the original cost of the house,—but only sufficiently high to maintain the property. No claim is ever made that this is a charity. The whole problem is treated as a business proposition which is paying, because the more wholesome and attractive surroundings rapidly improve the men and the value of their services. It requires no keenness of intellect to decide who have the better or more desirable life,—the worker at Port Sunlight or his neighbour in the surrounding Lancashire towns, with their dreary sameness, grimy cottages, and crowded streets. And the men and their families realise it. Illustrations of Port Sunlight are given on pages 522 to 525.

In 1901 the skilled labour of the sheet mills of the United States Steel Corporation went out on a strike,—not for wages, but with the purpose once for all to make it clear that their union, and not the management, would regulate work in the mills. Mr. Schwab, the president of the corporation, at first met the men in a most conciliatory spirit, offering to respect as "Union" those mills which had previously been so considered, but standing firm in his resolve to protect the independent non-union workers of the "open" mills. This was not a sufficient concession to suit the "champions of liberty," and the strike continued, with disastrous results for the union.

When the strike broke out over 30 per cent. of the men employed by the corporation were said to belong to the unions. When work was resumed only 6 per cent. of union employees remained. During the struggle the large mills at Vandergrift continued working. A union element existed also at Vandergrift, but it did not succeed in prevailing on the conservative majority of the men to leave their work. The reason unquestionably was the prosperity and well-being of the Vandergrift people.

At this place the American Sheet Steel Company had, in 1895, begun the laying-out of a modern workmen's town. Streets were graded, drained, and supplied with water, natural gas, and electricity. Schools, assembly rooms, a library, and a hospital were founded; building lots were sold to the workmen at fair, but not excessive, prices, and assistance was given in erecting houses by advanced loans secured by mortgages. A certain supervision was given to the style and construction of the buildings erected. The entire town government was placed in the hands of the inhabitants, but restrictions were made against the sale of intoxicating liquor and likely sources of disorder.

Thus was created, within the short period of six years preceding the outbreak of the strike, a most attractive, healthy, and comfortable town, which offered great advantages to the inhabitants, as compared with the congested manufacturing towns. The high wages paid encouraged habits of saving, and

THE LATE FRIEDRICH ALFRED KRUPP

when the Vandergrift people were at last called on to strike they found that the individual chances of loss were too great to justify them in attempting to obtain a power of which they never had felt the necessity. It may be interesting here to refer to the illustrations on pages 514, 515 and 516.

These are examples of the efforts of

THE PUBLIC THOROUGHFARE THROUGH THE KRUPP WORKS AT NOON-TIME

benevolent and far-sighted employers to ameliorate the life and conditions of the workman. Many other enterprises are in existence which aim at the same object. Some are successful; others less so; many have proven failures. It seems that a condition for success is the entire absence of all that savours of charity, and the accentuating of any feature which tends to bring out the worker's independence and self-reliance.

The liberality of Andrew Carnegie in the founding of libraries is another example of good-will, generosity towards, and recognition of, the workmen and their need of education. But, after all, these examples of practical interest are few, compared with the great number of employers whose relations with their workmen cease when the weekly wage has been paid. It is, therefore, not unnatural that the workman, on his side, is inclined to consider the reception of this wage as the principal object of his week's work, and that the less exertion he needs to put forth to secure this wage the greater is the gain to him. Add to this that the desire of some masters,—fortunately a minority,—is to make the wage as small as possible, while the workman's aim is to raise it to the highest possible point, and we have a not pleasant picture of the present labour situation as prevailing in some countries and districts.

It is not the writer's intention to deny the workman's right to ask the highest pay obtainable for his labour. It is his capital,—generally the only support of himself and his family. Nor is it but natural that the workmen in the same trade should combine in order to secure better compensation, to effectively point out and obtain relief from injustice, or to support one another when incapacitated or out of work. So far the labour or trade union is both necessary, unobjectionable and beneficial; but when it attempts to dictate to other workers whether they may use their own free will as to working or not working; when it tries to prescribe to the employer who is to be employed or promoted; whose services he should or should not dispense with; what encouragement he may or may not give to a deserving

employee; or how much product his works or shops should turn out, then the union is overstepping its bounds and must be fought with all fair means in order to save the industry which it threatens.

Trades unionism is probably here to stay. The only permanent and satisfactory *modus vivendi* must be sought in improving the unions by improving their members, by better training of the new generations of workmen, by educating them to become independent, rational thinkers, who will not be led by the enthusiasm or selfishness, as the case may be, of their leaders, and especially by encouraging and aiding the working class in saving.

There is a great difference between unions even to-day. Some are an advantage both to workmen and employers; others are the ruin of both. The American Society of Locomotive Engineers, for instance, is said never to have countenanced a strike, and to represent as conservative, competent, and hard-working a class of men as are to be found anywhere. With such a union most employers are found ready and willing to negotiate and to adjust differences that may arise.

The most effective aid in improving the condition of the industrial workman must, after all, come from himself. With the assistance they can get, the working classes must gradually strive towards a higher intelligence. This will enable them to enjoy a better class of amusements and recreation, and will teach them of the happiness and independence based on saving,—above all, of periodicity of saving.

America is here our example, and especially her industrial cities and country towns. Good schools, sobriety, and building and loan associations have been the levers which, with industry and good wages, have raised the American working class to its present generally prosperous condition. A great many workmen own the houses in which they live. This means that many of them are capitalists in a small way. The general prosperity is due to the numerous build-

A ONE-FAMILY HOUSE IN THE KRUPP WORKMEN'S COLONY, ALFREDSHOF

A COMPANY DEPARTMENT STORE AT CRONENBERG. HERE NECESSITIES AND LUXURIES CAN BE BOUGHT FOR CASH, AT FAIR PRICES, ONLY BY KRUPP EMPLOYEES

ing and loan associations, which have placed at the disposal of the workman early in life a sum of money sufficient to found a home, even though he may have been entirely friendless and unable to furnish any security. These associations have afterwards trained him to habits of periodic saving, and have given him that hope of the future which is the most precious possession of humanity.

It is difficult to agitate amongst people who own property. The most astute and most silver-tongued labour agitator stands helpless before the man who can feel the bankbook in his breast pocket and knows that it shows a comfortable balance, and who may have a vague impression that the efforts of the plausible talker interviewing him might reduce this balance.

Here is the best solution of the labour question, and one which is easier to arrive at within a well-managed iron and steel trade than in most other industries, because with proper plant the number of men employed should be comparatively small and the output per man should reach a high value, justifying high individual wages.

When bidding farewell to his workmen at Pittsburgh in 1900, Andrew Carnegie was able to state that they were the highest-paid body of workmen in the world. Given a continuance of good wages, good general education, and liberty,—which does not mean license,—and the workmen as a class will gradually free themselves from grinding poverty, from union despotism, and from unjustified bitterness and ill-will towards their employers. Grumblers, discontents, drunkards and spendthrifts there will always remain, whatever the conditions; but the position and status of the working population, as a whole, will surely improve.

The labour question, with all its difficult and intrinsic problems, is the pivot on which the future of the iron and steel trade will turn. A class of well-drilled,

self-respecting, and intelligent workmen, who perhaps may share in the ownership and interest of their business and its success, will be the strongest lever for the advance and perfection of their noble industry.

Mr. Schwab has pointed out that the United States Steel Corporation by offering their shares to the public enables their workmen to become part owners in the business which employs them. How far they will avail themselves of this opportunity in some distant future to acquire ownership and eventually control of industrial corporations it is hopeless to conjecture; but the appearance of workmen stockholders, in sufficient number and of sufficient intelligence, may some day compel the operation of their industry to be carried on for the benefit of all those interested in it and might bring us to the verge of the best form of socialism. Further than this our present light will not permit us to see.

Here we stand as helpless and puzzled as would have been our great-grandfathers before the telephone or the phonograph. Coming generations will, and must, take up these problems. They will be better equipped than we are to solve them.

MACHINE TOOLS WITH INDIVIDUAL ELECTRIC MOTORS

By R. T. E. Lozier

Variable-speed electric motor control was the special topic of discussion at one of the recent meetings of the American Institute of Electrical Engineers. Several papers were read dealing with it, one of them, by Mr. Lozier, concerning itself particularly with the use of individual motors for machine shop service, and this has been here reprinted in part, and with some additions to the original.—THE EDITOR.

THE individually-applied motor is now accepted as an established feature of every well-equipped machine shop. The period of careful investigation, followed by that of cautious probation, is past, and this type of power application has now been in practical service sufficiently long to provide data that can be studied with profit. These data enable one to make more accurate deductions than were possible in the past, and enable those unfamiliar with the art to undertake its application with greater certainty of securing desired results.

From the data that have been collected on power transmission in industrial shops it appears that if a certain maximum horse-power is required by all the tools of a shop, say, 100 H. P., it will require at least 100 H. P. additional to transmit this effective power by belts and shafting. This loss of 100 H. P. remains constant whether the effective horse-power is reduced or not. This means that 200 H. P. must be generated. Should these same tools be driven by individual motors, instead of 100 H. P. being required for transmission, only 43 H. P. would be required, even with every tool running; but it is found that in the average industrial shop every tool is not running at the same time, some being shut down and others operating on lower than maximum speeds, thus requiring less horse-power.

It has been determined practically that in the ordinary manufacturing establishment the mean effective power is but 30 per cent. of the aggregate effective power which is required when all the tools are running at maximum load. This percentage is termed the load factor.

It has been shown that in an average machine shop with the shaft and belt system the power cost may amount to 2 per cent. of the cost of the establish-

ment's product; with sub-divided motors it may be taken at 1 per cent.; and with individually-driven motors it may run down as low as 0.4 per cent.

Assume that in the average machine shop 60 per cent. of the motors installed are to have variable speeds. These variable-speed motors will have a rated capacity considerably higher than the average amount of power which they will be called upon to supply. Assume that the rated capacity of the other 40 per cent. represents the exact amount of power that they will consume,—and this assumption is justified because their speed is not varied. Of the sum of the total rated capacity of the variable-speed motors and that of the constant-speed motors 35 per cent. fairly represents the mean power that all of these motors will be required to furnish, if they are all running at the same time. This mean power, of course, varies with that percentage which the variable-speed motors bear to the total installation. If the load factor of 30 per cent. be now applied,—which provides for the shut-down of tools and reduction in the power due to slow speed,—it is found that the average power that must be provided by the generating plant is but 10.5 per cent. of the aggregate rated capacity of the individual motors installed. While it is true that 60 per cent. of the motors have a much larger rated capacity than is actually required, still this very small amount of power required is an evidence of the remarkable efficiency of the individual drive system. It cannot be assumed that these 10.5 per cent. are the capacity of the generating plant required, because provision must be made for maximum conditions. However, the system is so efficient that ample margins of, say, 100 or 200 per cent., can be applied, which may also provide for "stand by" purposes. And yet the purchaser who applies this individual motor system comes well within that power plant which he would otherwise have to supply to meet the mean conditions of a belted plant, without providing any "spares" for the latter.

The writer feels that if it were not for the empirical data presented, time would be wasted in stating an already well accepted fact, *i. e.*, that the individual motor-drive is highly efficient, and many times more so than the old system of belt transmission, or its modification of belted motors in groups. It is not claimed that the latter itself has not a sphere of usefulness, and that a large one; the foregoing is merely a comparison of the relative economy of these different systems.

It would not be possible to use the individual motor if means were not available for successfully varying its speed. To control the speed of a motor it is necessary to apply to the armature terminals a voltage corresponding to the speed desired. This can be accomplished in several ways:—

The Rheostatic Method.—In this case the current is generated at any ordinary source of supply at a fixed voltage. Before reaching the motor it is passed through a resistance which is adjusted to consume just so much of the voltage as will reduce the speed of the motor to the point desired. This method has three limitations, viz.:—(*a*) that if the load put upon the motor varies, the proportion of the voltage consumed in the rheostat is altered, and this changes the speed of the motor, which may not be desirable; (*b*) the system is inefficient, because that percentage of the voltage which is consumed by the rheostat represents a dead loss; and (*c*) the dimensions of the rheostat necessary to dissipate the energy may reach an inconvenient size. Within its limitations, however, the rheostat system of control can be made very useful. The motor cannot be reduced from its normal speed more than 50 per cent., because below that point the fluctuations in speed, due to variations in torque, are too great.

The Multi-Voltage Method.—This method consists essentially in supplying the motor with as many different voltages as are necessary to cover the desired range of speed. In its simplest form this method consists of generators, each adjusted for different potentials. This, however, is not necessary, because it has been found that where several motors are involved they will balance

up against one another in such a way as to divide amongst themselves the full voltage, so as to give the respective desired speeds. It is, therefore, necessary only to supply the main generating plant with a small balancer to take up any differences that there may be. By dividing the voltage at three points there are six possible combinations which successfully cover the full range of speed as far as general requirements are concerned. The advantages of this system are:—(*a*) that any one of the lower steps can be maintained constantly and quite independent of variations in the torque or load upon the motor,—this is absolutely essential to successful tool operation; (*b*) that the system is highly efficient; (*c*) that appliances to control it are of very small dimensions and convenient to operate.

Special Methods.—In this class are to be found various methods which have been devised to meet the special requirements of some one power application. Among these is the teaser system, which consists essentially in employing a small motor taking current from the main source of supply at the full voltage. This motor drives a small generator wound for large current capacity, and this current it supplies to the main working motor, but at low voltage, because the speed is very slow. It is because of the latter fact, and, further, because it is in service for so short a time, that the apparatus can be made small.

Field Control.—The foregoing methods vary the voltages applied to the terminals of the motor armature. There is a method of changing the speed by varying the field strength of the motor. This has two limitations, one being that as the field of the motor is weakened, it goes farther and farther off from its electric balance, and its distress is soon evidenced by sparking at the commutator, due to reaction of the armature upon the weakened field. The other point is that the torque will fail if the field is weakened beyond a given point.

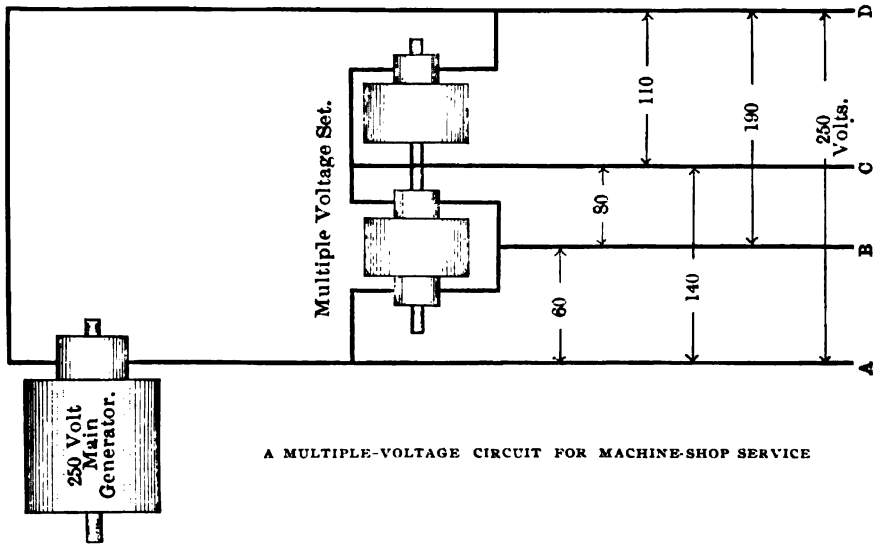
In a motor designed to come fairly well up to the limitations of its normal rating, the speed should not be increased more than 30 per cent. If, however, the motor is large for its work, *i. e.*, underrated, according to commercial standards, then, of course, its speed can be increased until the limiting conditions of speed control, as established by its rating, are again reached. Or if the motor is operating at a lower potential impressed upon its armature than that of its normal rating, its speed may be increased over a larger range by weakening its field. But, generally speaking, it is well to understand that field control, while most useful within its limitations, cannot be successfully carried beyond such limitations, and that such limitations represent an increase of not more than 30 per cent. of the normal speed of the motor. It must always be remembered that field control increases the normal speed of the motor and does not decrease it.

In combination with the multi-voltage system,—which is available for producing certain speeds that remain constant, even with varying torque, throughout the entire range,—the rheostatic control can be used for reducing any one of the fixed speeds to the next fixed speed. Field control can also be used for increasing any one of the fixed speeds to its next graduation. By these means speed increments can be obtained as finely divided as one pleases that will carry the speed of the motor from zero to maximum, with high efficiencies and practical constancy at any one point, in spite of varying torque. The multi-voltage is depended upon to form the frame-work of the speed control, while the rheostatic and field control supplies the detailed elaboration, where such may be necessary. The multi-voltage is carried throughout the entire plant, usually by two conductors in addition to the two main circuits, while the rheostatic and field control is applied locally as circumstances may require.

Edison marked an important epoch when, about seven years ago, in his ore-milling undertaking, he put into operation a principle that had long been accepted by him,—that machinery and equipments are cheaper than labour and general expense, and that it is better to use up the machinery at a high rate, if

by so doing the output is materially increased.

About four years ago the matter of determining exactly the speed limitations of metal working machinery was taken up by a few enterprising engineers, and these limits have since been kept in view with the greatest degree of success. Where formerly the old



A MULTIPLE-VOLTAGE CIRCUIT FOR MACHINE-SHOP SERVICE

thumb rule governed, the slide-rule is now used. While labour was bitterly opposed to the principle of the employer inducing his operators by additional incentive to work up to the highest efficiency,—which incentive was withdrawn when that point was reached, and their wages perhaps still further reduced should they fall behind,—it has been led to recognise the benefits to be obtained by securing to the operator his mean wage, and allowing him to share in the benefit gained by his working up to his normal capacity.

These methods at present come within two general classifications. I will mention them here, because they are pertinent to the general subject of variable speed control. The first is the premium system, in which the law of averages is applied to past work and the result is taken as a standard for determining what can be done in the future. This determined amount is generally cut down in order to provide for the increased efficiency at which the man is supposed to work. Now, if a man is able to improve upon that time, he is given a *pro rata* share of the gain. This system is based upon empirical data.

The other system is more recent, and is known as the bonus plan.* In this the limit of speed and depth of feed are determined; then the area to be traversed by the tool determines the minimum time in which the tool can traverse it at its maximum cutting speed and depth. In making this calculation, it is assumed that the operator has always available the speed that represents the maximum limitations of the tool. Stability of the machine tool itself, and the capacity of the power transmitted to do the work, must be carefully considered. The operator is given explicit directions as to the shape of the cutting tool, the feeds, speeds and general method to be applied in doing the work, and the exact time involved in such method is also given him. These instruction cards are not only theoretically correct, but state conditions that can easily be obtained

* Articles on both the bonus system and the premium plan appeared in this magazine for November, 1902, and January, 1903.

in practice. If the operator succeeds in meeting these conditions he not only receives his regular pay, but is also presented with a fixed bonus. With such a method of operation as has just been described the practical operator immediately recognises the essential points.

1st.—He must have a cutting tool that will stand up to the work.

2nd.—He must have a motive power with a range of speed from which he can always select, and quickly, the speed that will produce the result expected. This motive power must be able to stand up to its work.

3rd.—The machine tool must have sufficient strength to stand the strains that may be put upon it.

The limit of high-speed operation is not to be found in cutting tools, or in the ability of motors to successfully do the work and to vary their speed, or in the motor's first cost, but in the stability of the machine tool itself, which is generally designed to stand only the lower strains and powers required by the old cutting rates.

What the writer would particularly point out here is the close relation that the individual motor with its variable-speed drive bears to what is now known as the new shop method.

When I refer to it as "method," I probably ought to say "methods," for there are a number of means for increasing shop production. These methods were first evolved probably not more than four years ago. Perhaps Edison was one of the first to enunciate the principle that it is better to waste the tool if you can save your labour. He put this theory into practical operation, and for years has worked to the end of increasing his product as being the most practical means of increasing his profit.

Investigations were made, beginning about four years ago, at one of the largest steel works, and large sums were expended in experimenting, not only with tool steels, but also with variable speeds. It was found that the general machine shop practice was very far behind its possibilities. Under the old methods the man who had served his apprenticeship was turned over to the blue print and stock, and by the rule-of-thumb he got the best out of the stock that he could. Modern tools, instead of applying the thumb rule, apply the rule best adapted to the work, and increase the output from 100 to 200 per cent., and in some cases to 300 per cent. This is an enormous increase. It means that a shop which has been in the habit of working day-time and night-time, can increase its output by working only day-time and shutting off its night force. I was told recently by the superintendent of one of the largest shops that by variable-speed motors they increased their output over 40 per cent., and so I say that the variable-speed motor bears an intimate relation to the new shop methods.

The multi-voltage circuit involves a given source of supply,—isolated plant or central station,—having two wires, and a balancer. The latter is not, as is generally supposed, a large device, having a capacity sufficient to carry all the motors at the lowest speed, any more than a life insurance company is organised and premiums adjusted on the basis of all the policyholders dying the same day. The larger the number of tools driven, the smaller the balancer may be; and we have taken it as a rule that the armature of a multi-voltage balancer need not be larger than sufficient to operate the largest single motor on the circuit at its lowest speed. This rule is borne out in practice in a number of cases.

It may be interesting here to refer to the diagram on the opposite page, which illustrates an example of multiple-voltage circuit best adapted for machine shop service, as it gives the range of speeds most suitable for driving machine tools. The lights in the factory would be connected between C and D, giving 110 volts. Constant-speed motors would be connected between A and D, giving 250 volts for these motors, and the variable-speed motors would be furnished with multiple-voltage controllers which would enable making any connection desired to give the different speeds.

If the armature terminals of a motor

are connected across *A* and *B*, the armature will receive 60 volts; if across *B* and *C*, 80 volts; if across *C* and *D*, 110 volts; if across *A* and *C*, 140 volts; if across *B* and *D*, 190 volts; and if across *A* and *D*, 250 volts, thus affording six different speeds. The speed of the motor is nearly in proportion to the voltage, varying from 60 to 250 revolutions per minute, or in this ratio.

The fields of the motor will be constantly excited across any one of these voltages. If it was a 110-volt motor originally, the field terminals on the motor would be connected between *C* and *D*, and if it was a 250-volt motor, the terminals would be connected between *A* and *D*. The example here given is what is termed a "four-wire" system.

EARLY AMERICAN HIGH-SPEED ENGINES

RECOLLECTIONS FROM A PAST GENERATION

By John E. Sweet

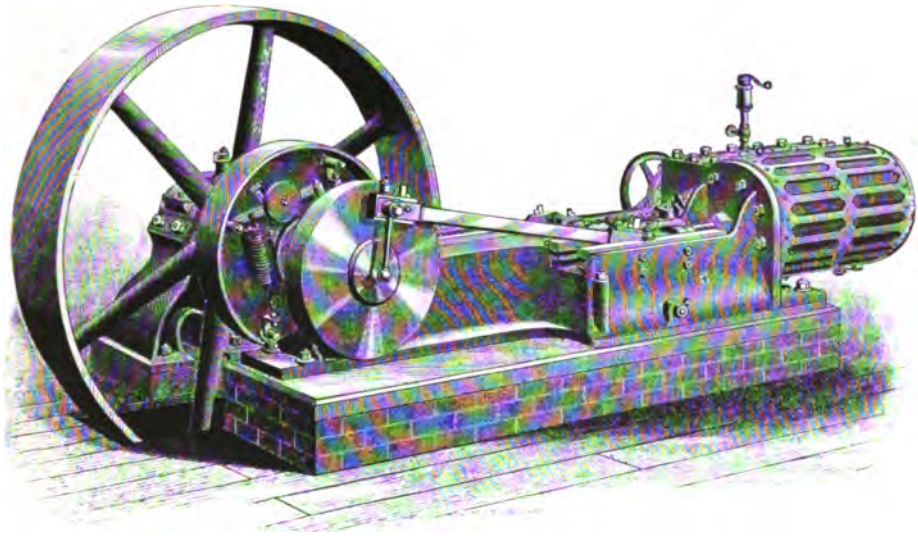
Professor Sweet's recollections of American high-speed engine history were first presented in the form of a paper read recently at a meeting of the Engine Builders' Association of the United States. In the light of what is known now of high-speed engine work, those early experiences are peculiarly interesting, and the value of their reproduction here has been enhanced by the addition of old-time illustrations of most of the engines mentioned.—THE EDITOR.

THE PORTER ENGINE

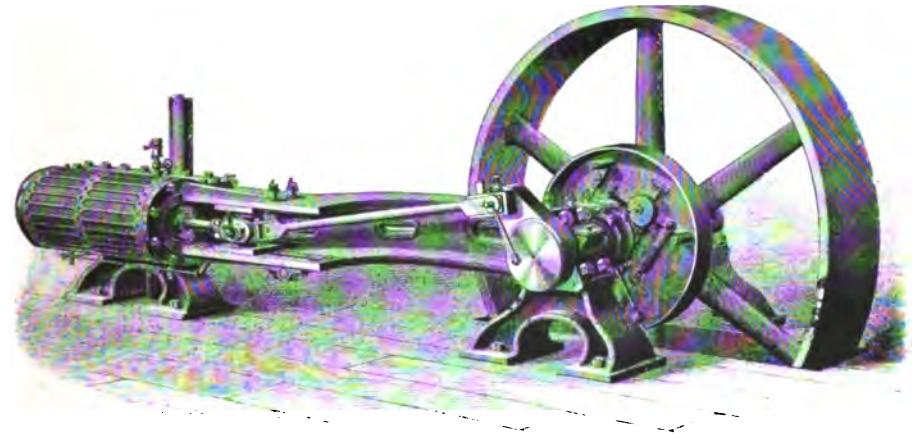
IN 1862 Charles T. Porter exhibited at the International Exhibition, London, an 8 × 24-inch engine running at what seemed then a fearful speed, 150 revolutions per minute. This was afterward set up in London and ran 225 revolutions. While I was there and saw this engine in the exhibition of 1862, my mind was occupied in other directions, and I paid very little attention to it. I did, however, see Mr. Porter, and copied for him the drawings of the Richards indicator on parchment for his patent attorney.

I became acquainted with Mr. Porter later at the Paris Exposition of 1867, where he exhibited four high-speed engines and a model, all built by Whitworth, of Manchester. Two of the engines ran dynamos, the first I had ever seen; I do not remember whether direct connected or not; the other engines were, one a 12 × 24-inch, running 200 turns a minute, driving a part of the English machinery, and the other a 6 × 12-inch, running 750 revolutions idle, I believe. I think 400 revolutions were about its normal speed. The model of the engine, a complete 6 × 12-inch, was split directly through the cylinder, which was to me a wonderful thing. From what I know now I do not believe that any such pieces of workmanship as these engines were could have been made at that time in any engine shop in the United States, and I say this in the full consciousness of the fact that Corliss had a silver-plated engine in the exhibition at the same time. Corliss received a gold medal, a fact thoroughly well-advertised throughout the United States, as did also Mr. Porter and a half dozen others, which was not so well known.

Mr. Porter's engines shown at Paris had the same bed as that designed by him in 1863, a design that has been



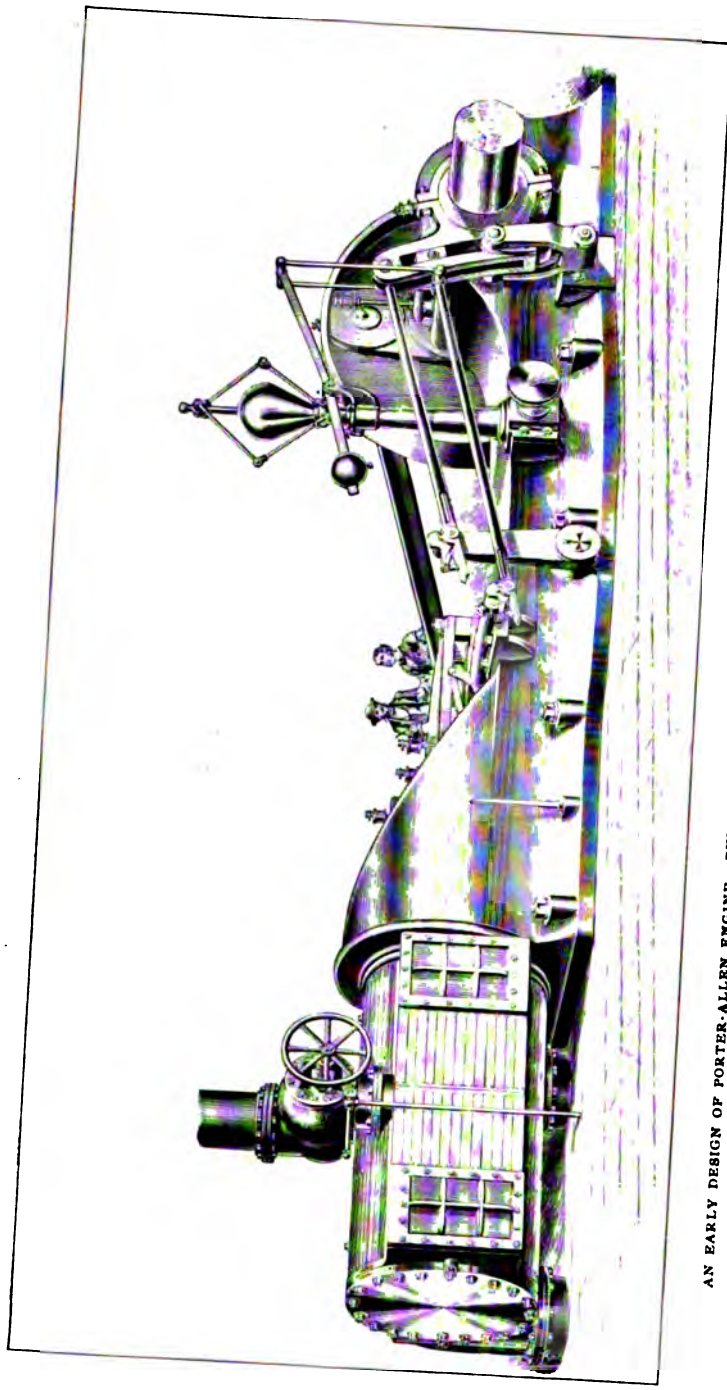
THE EARLIEST HIGH-SPEED AUTOMATIC ENGINE BUILT BY THE BUCKEYE ENGINE COMPANY, SALEM, OHIO, U. S. A. THIS ENGINE WAS MADE WITH 6, 7, 8, 9, AND 10-INCH BORE, ALL OF 14-INCH STROKE



THE EARLY BUCKEYE MEDIUM-SPEED ENGINE

copied more, except the Corliss, and lived longer unchanged than any other, and though it has been copied, imitated, changed, modified and counterfeited by others, it has never been improved upon. Tangye Brothers, of Birmingham, England, adopted a modified form of it years afterward.

I do not remember just when it was, but think it was at this time, that Mr. Porter explained to me his conception of a marine governor, which, as I now remember, was simply forestalling what we are all using, a spring to resist the centrifugal force of the governor balls, instead of depending upon gravity, as had always been done before.. This resisting the centrifugal force of the governor ball by a spring instead of gravity means a good deal more than at first sight would appear. Centrifugal force increases directly as the radius of rotation, and a spring's resistance increases in a direct ratio also, which makes it

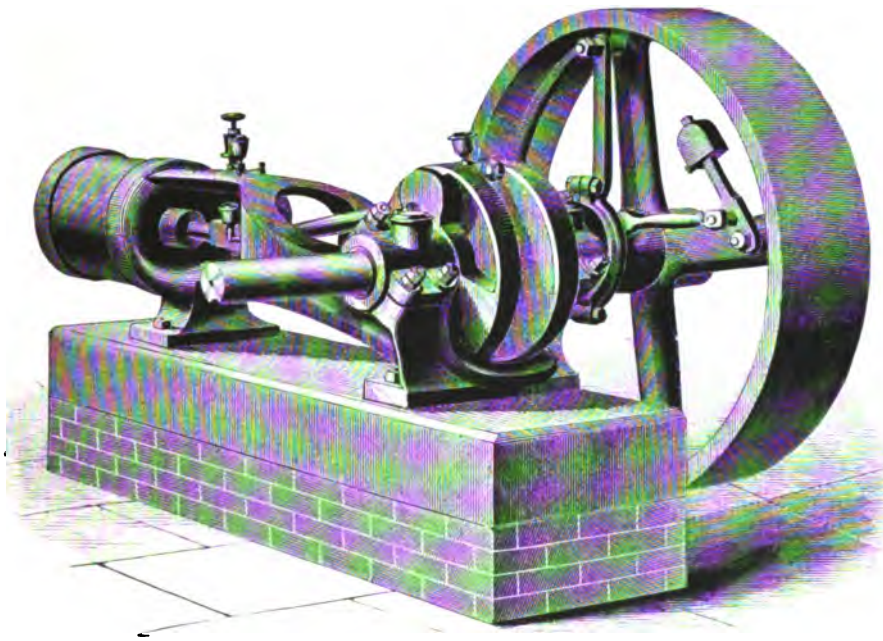


AN EARLY DESIGN OF PORTER-ALLEN ENGINE. BUILT BY THE SOUTHWARK FOUNDRY & MACHINE COMPANY, PHILADELPHIA, PA.

easy to establish a delicate state of equilibrium in all positions of the governor ball; whereas with gravity, which remains constant, the pendulum arms have but one position when they are just right, and give a very small range of good results.

Mr. Porter did more; he introduced refined workmanship in engine building in the United States,—the first, I believe, to make mechanically fitted valves on flat planes; introduced the better indicator, and did, besides, a great amount of scientific work, original and valuable to all who have made the nature of heat engines a study; and, in passing, I may say one thing more,—no man, unless it was Zera Colburn, has, to my mind, ever been able to write on mechanical subjects and make his thoughts so clear and use such admirable language as Charles T. Porter.

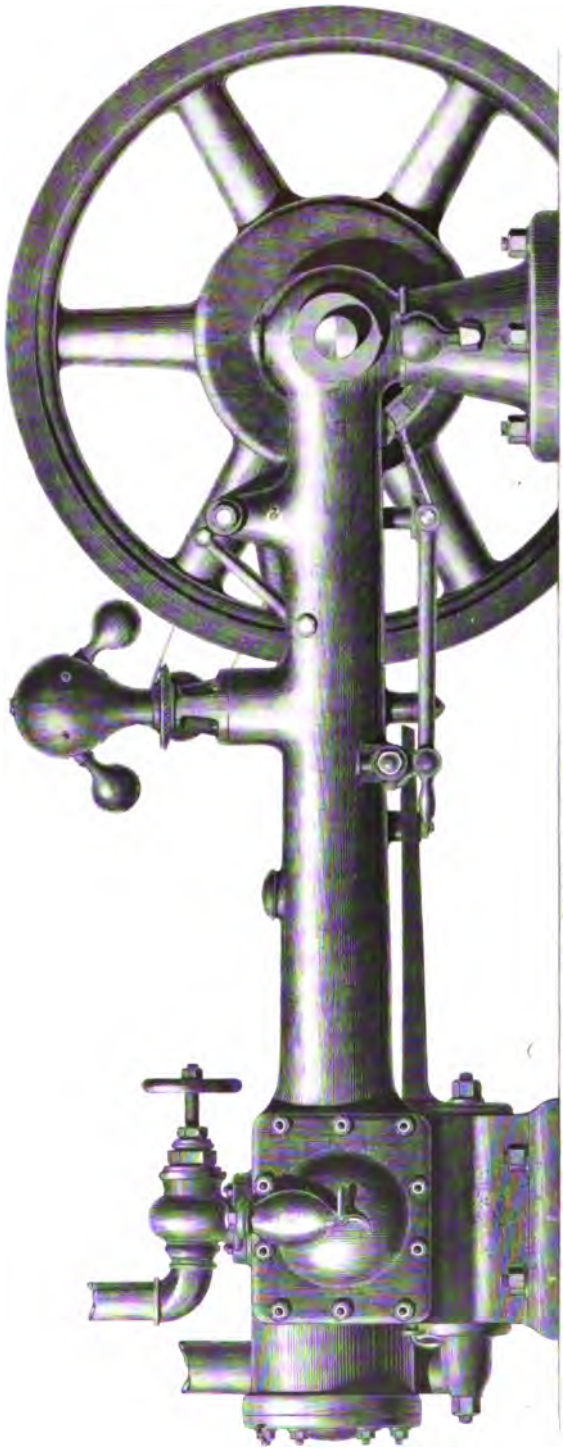
Along in the early seventies the business of the Porter-Allen Engine Company was started in Harlem, and met with disaster, owing to a combination of adverse circumstances. The engine was later built by the Hewes & Phillips Company, of Newark, and since by the Southwark Foundry & Machine Company. It is likely that the Porter-Allen has had as few changes in its mechanism since its first completed form as any, with the possible exception of the Buckeye engine. Corliss, it will be remembered, modified his design just before he died, and it then had what seems to us now a long life without change; but I doubt if as long as the Porter-Allen, now nearly forty years.



THE EARLY ENGINE MADE BY MESSRS. B. W. PAYNE & SONS, NOW THE PAYNE COMPANY, OF ELMIRA, NEW YORK

THE BUCKEYE ENGINE

The first I ever saw of the Buckeye engine was at the Centennial Exhibition, at Philadelphia, in 1876, when a standard slow-speed and a small high-speed engine, such as they had been building for twenty years, and coupling direct to circular sawmills, were exhibited. The small engine ran at a fearful speed. I understand they ran at 500 or 600 revolutions per minute, but the service was rather favourable for high speed, as they ran light during the return of the car-

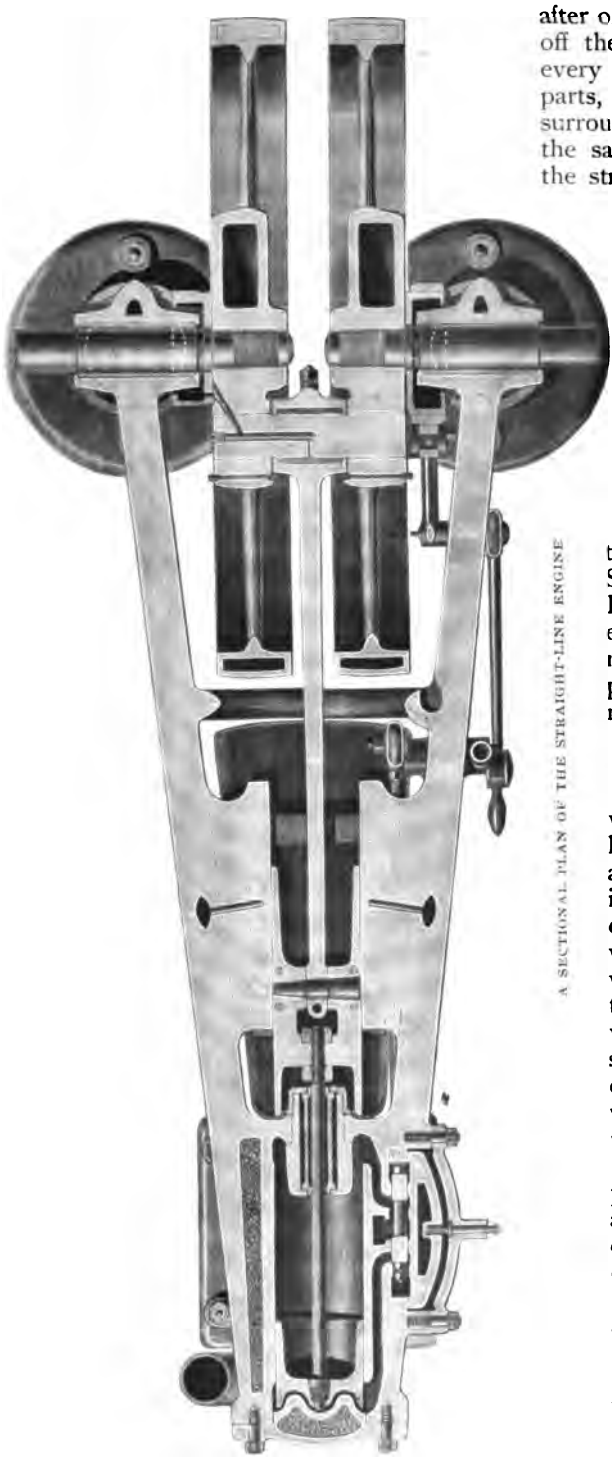


THE STRAIGHT-LINE ENGINE, 1872

riage, and, too, there was no governor to bother with, the engine being run by the throttle, which reduced the mechanism to its fewest parts. In this connection I cannot do better than to quote the following from J. W. Thompson, the inventor:—

"Very high-speed engines directly driving mulay saws were built in the forties, but the days of counters were not yet, so the actual speeds attained will never be known; but I am very sure of having seen speeds exceeding 400 frequently and sometimes near 500, but the generality of rural sawmill men seldom exceeded 300 revolutions. These engines were built by Sharp Brothers previous to 1850. The firm of Sharp, Davis & Bonsall was organised in December, 1851, and as soon as large circular saws came into use they were attached direct, and I am tolerably sure that a speed of 600 was frequently reached. The engines were all throttling, run without governors, the sawyer having the throttle at his hand constantly and admitting steam as required. For quickness of control butterfly valves were used, absolute tightness of closure not being necessary, as a stop valve was provided for stoppage when required.

"No automatics were built here until the formation of the Buckeye Engine Company, but very high-speed engines had their drawbacks. I have frequently seen wornout crank pins, the wornout part on the inner side so nearly central with the crank line as to show that about nine-tenths of the wearing strain was due to the momentum of the reciprocating parts. On the outer side of the pin a strip of the original shop finish generally remained visible



A SECTIONAL PLAN OF THE STRAIGHT-LINE ENGINE

after one-eighth or more had been worn off the inner or shaftward side. Yet every device was used to lighten the parts, even to making basswood pitmen surrounded with light straps; but when the saws were not kept in best order the stress often greatly exceeded the factor of safety. -The wooden pitmen were soon abandoned with the advent of the circular saw, but nothing but wooden pitmen was ever used here to connect the saw to its crank."

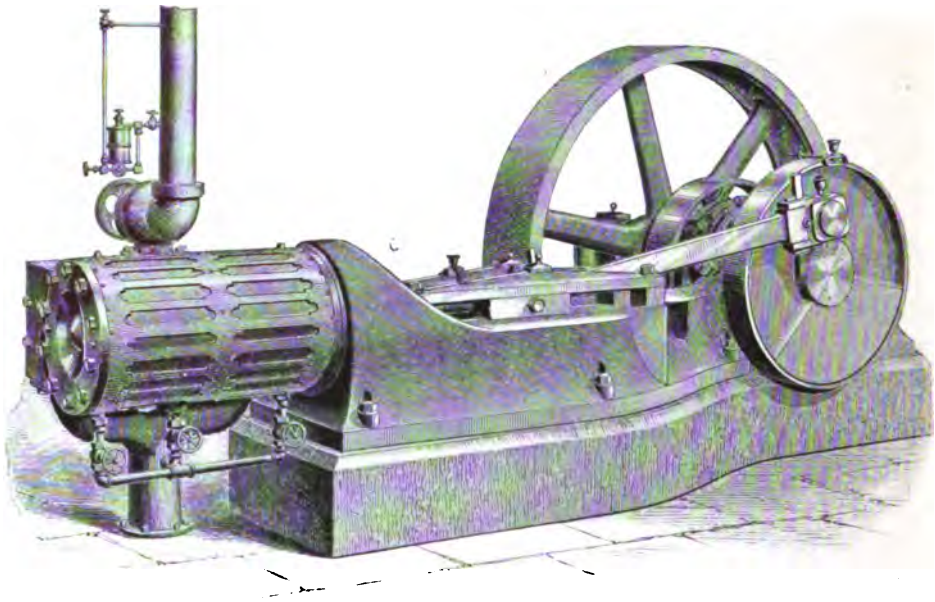
The large engine was, as it is now, a shaft-governed engine, and, so far as I can recollect, practically like their present standard machine, but was not high speed.

Some years before the Centennial, Messrs. B. W. Payne & Sons, of Elmira, New York, were, I heard, building shaft-governed engines, as were also Hall & Whitmore, of Havana, N. Y., but not particularly high speed, as I remember them.

THE STRAIGHT LINE ENGINE

The first Straight Line engine was built in 1872, purely to try a lot of experiments. I was well aware of the fact that, in general, it is not good practice to try two experiments at one time; but this was a different thing. To tell whether a long piston was better than a short one did not interfere with trying to find out whether a solid box was the thing for an engine main bearing, and these were the sort of experiments that were coupled together.

It is doubtful if ever more departures were made in any standard machine than were in that conglomeration of mechanism,—casting the frame with the cylinder; making the frames straight and resting the whole on three points, with one unfastened; casting the jacket on the cylinder, with solid cast-iron boxes and ring oilers; putting the fly-wheels on the throws of the centre crank



THE ARMINGTON & SIMS ENGINE OF 1881, THEN KNOWN AS THE LAWRENCE ENGINE

and building the whole up, which was then new, and thus putting the fly-wheels between the frames; using a long piston, one equal to the diameter of cylinder, secured to the rod in a new way (fastening the end in the crosshead by a half nut); a crosshead so long and guides so short that the two were of the same length; a crosshead pin tight in the connecting-rod and with two bearings in the crosshead; connecting-rod of steel casting, half of the box cast on, oiled through the crank-pin and a different method of oiling the guides. A single valve of the Porter-Allen type performed all the functions of a slide or piston valve. All the pivots, except the crank taper joints, had take-ups endwise. There was a novel governor of the fly-ball pattern, in which the ball travelled in an elliptical curve, which closely conformed to the parabola which had been determined to be the true form.

In the old days there was about as much high science spread over the fly-ball governor as there has been in recent years over the shaft governor, and it came to an end about 1880 on the Cosine governor, about which there was a great ado. This Cosine governor was nothing more than the governor on the first Straight Line engine, scientifically developed rather than being made by hand. The governor controlled a sliding block in a link and varied the cut-off. The engine ran, off and on, for a number of years, and in a dozen different places as a helper in emergencies, ending up as the central figure in the Straight Line Engine Works.

The experiment proved a good many things; about as many things that would not work as would. The long piston was a miss and a go. When these pistons did not get to cutting, they went very well; but they were more likely to cut than the short ones, or at least that seemed to be the conclusion.

The rods through round holes proved successful when we found out how to make the holes. The taper crosshead pin would not do, but the long crosshead and short guides were right. They were made straight, and never wore out of straight,—in fact, never wore much anyway, and this, with the many other experiments I have tried, has established the fact that things which do not tend to wear out of truth do not wear rapidly.

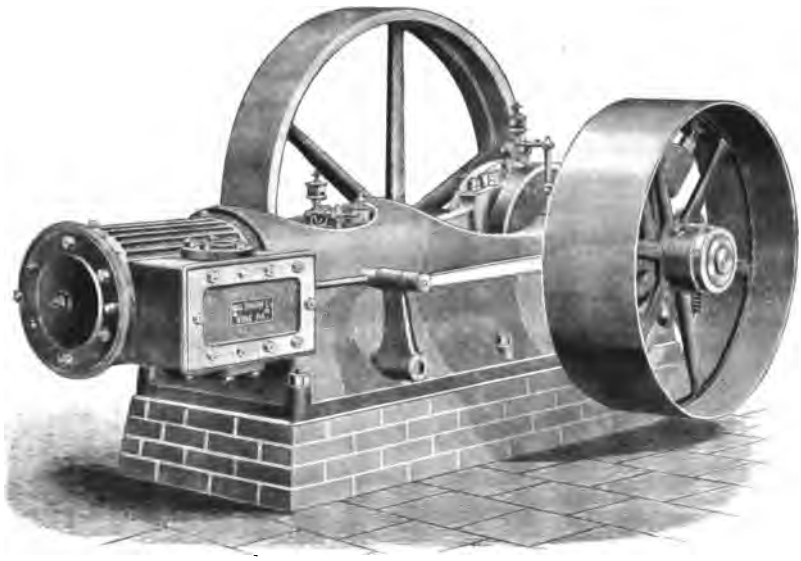
The oiling of the crosshead was a failure; that of the crank was a success. The solid boxes were right in one respect and wrong in another, and led to a compromise that was better. The frame and wheels within the frame were right and the governor was all wrong. The valve, as then made, was wrong, but made so successful later as to be what it is known to-day.

THE SHAFT GOVERNOR

Between the time this experimental engine was built and the one built in the workshop of Cornell University and shown at Philadelphia in 1876 the shaft governor with shifting eccentric began to take on shape. I had heard about it and had seen the Hall & Whitmore engine, but none with a shifting eccentric; but so built the engine shown at the Centennial, where I first saw the Hoadley portable, which also had a shifting eccentric and shaft governor, the Buckeye being, as was the Hall & Whitmore, a governor rotating the eccentric around the shaft controlling a cut-off only.

It may be proper to remark that the Cornell engine was belted to the first Gramme dynamo ever built in the United States, which was also built at Cornell, the Gramme dynamo being the father of all direct-current dynamos, and the three elements, an engine, dynamo and electric lights combined, were the first shown in the United States at an exhibition, I believe.

The governor of this engine shifted the eccentric by wedging it over by rotating a short piece of a primary eccentric in a way similar to the Armington & Sims plan, and it operated the dog leg rocker arm, which gave a constant lead at both ends of the cylinder. This was one of the many ingenious inventions that did not need to be made.



THE BALL ENGINE AS FIRST BUILT IN 1883, BY THE BALL ENGINE CO., ERIE, PA.

At the time it was made it was supposed, and so stated, that with a shifting eccentric a constant lead could not be obtained, and that was the objection to the shifting eccentric.

A good many designers have thought that the trouble was due to the fact that the eccentric moved on the arc of a circle instead of going in a straight line, but that has nothing to do with it. The distorted rocker arm corrected the lead; but, as said above, that was not wanted.

THE FIRST IDE ENGINE, WITH MR. IDE AT THE THROTTLE

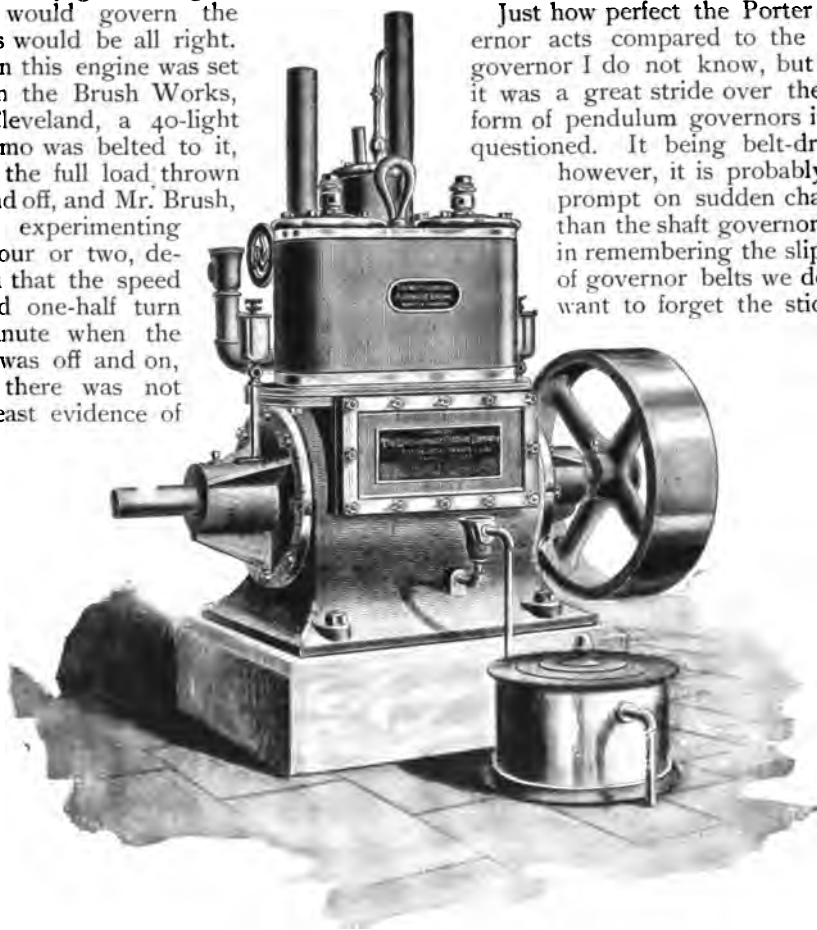
Soon after going into the business we found that out, and the variable lead was adopted about 1882.

Until 1880, as I remember it, the Porter-Allen Engine Company were the only ones making a business of building high-speed engines, and they were neither centre-crank, single-valve, nor shaft-governed. The B. W. Payne Company had been building shaft-governed, centre-crank, and piston-valve engines for a year or two, but not exclusively, and somewhere about this time the Hall & Whitmore people went out of business; Mr. Hoadley had gone likewise.

The three Straight Line engines built before and during 1879 were more or less experimental. In the autumn of that year building was started as a business in a small way. The first engine set to run a dynamo regularly was in 1881, and the incidents connected with it are appropriate to record, because while it is known that the electric light business helped to build up the engine business, it is not generally known to what extent the high-speed engine

A REAR SECTIONAL ELEVATION OF AN EARLY ENGINE, BUILT BY MESSRS. A. L. IDE & SONS, SPRINGFIELD, ILL.

helped the dynamo business. The electric light people were at this time building only arc-light machines, and they were having a good deal of trouble in the flicker and unsteadiness of their lights. The excuse was that the engines did not govern, and that if they could only get an engine that would govern the lights would be all right. When this engine was set up in the Brush Works, at Cleveland, a 40-light dynamo was belted to it, with the full load thrown on and off, and Mr. Brush, after experimenting an hour or two, decided that the speed varied one-half turn a minute when the load was off and on, and there was not the least evidence of racing. This settled the question of an engine's governing, and disclosed the fact that the trouble, if any remained, was elsewhere. I mention this because this was before good governing had begun to be talked about, and there has been no change since, so far as the principle of its action is concerned.



THE FIRST STANDARD ENGINE PUT ON THE MARKET BY THE WESTINGHOUSE MACHINE COMPANY, PITTSBURGH, 1883

The governor designed by Mr. Porter to control the link-block in the Allen engine is still in use on the engine, largely in use in Europe in various styles of engines, and is used by some other builders, who designate it as a central weight governor, though it is a Porter invention, nevertheless.

Just how perfect the Porter governor acts compared to the shaft governor I do not know, but that it was a great stride over the old form of pendulum governors is unquestioned. It being belt-driven, however, it is probably less prompt on sudden changes than the shaft governor; but in remembering the slipping of governor belts we do not want to forget the sticking of governor pins. Having gone rather extendedly into the history of Mr. Porter's, the Buckeye and my own work, it is in order to follow Mr. Hoadley and Gardiner C. Sims, who were working together at the same time I was, but at first on a little different line.

Mr. Hoadley's exhibits at the Cen-

tennial, where I first met him and Mr. Sims, as well as that of the Buckeye people, were portable engines, with the exception of a little one, not running, and which he called his Meerschaum, because of its resemblance to a pipe, and which he later designated the Chronometer, because it was made to run in all positions. His portables were centre-crank, shaft governed with shifting eccentric, single-valve engines. His governor was quite unlike our modern practice, having two double elliptic springs, practically like carriage springs, to resist the centrifugal force of the weights, and some peculiar lever arrangements which I cannot describe.

Mr. Hoadley's original patents on the governor went back to 1872; though that as a shaft governor was antedated by various other shaft-governor patents, it carried a new form and was father to others that have appeared as original. In Mr. Hoadley's work Gardiner C. Sims was a co-worker, and just how much credit is due each one would no doubt have been hard for either of them to say.

Of the early builders of shaft-governed engines in the United States, Mr. Hoadley's patent of 1873 probably is first, and I believe this engine, started on April 1, 1873, the very day I started my first engine, was the first shaft-governed engine ever run in America,—that is, as a business proposition. It is more than likely that other inventors may have experimented before, but it seems no one in the United States who continued in business anticipated Hoadley's and Sims' work. Their work, however, in the early days was not just what we are now considering,—that is, the centre-crank, shaft-governed, high-speed engine. The Cornell engine exhibited at the Centennial in 1876, built in 1875, seems to have been as early as any.

B. W. Payne & Sons exhibited their first engine in the showroom of the American Electrical Company in New York in 1879, with the Tabor governor; Armington & Sims their first engine at the Paris Electrical Exhibition in 1881 direct connected to an Edison Jumbo dynamo, using the same governor up to the present time, I believe.

The Westinghouse engine was first built for direct connection to a dynamo for a locomotive headlight; in 1882 three were built, with shaft governor outside, and in 1883 their first standard engine was put on the market.

The first Ide engine was built in the latter part of 1882 and one exhibited at the Railway Exhibition in Chicago in May, 1883. This engine had a single ball governor, but when I advised Mr. Ide that I had a patent that covered this form he at once acknowledged the claim and abandoned that form for a time; but later, after using the two-ball governor, he found it worked just as well with one as two, and so simply left one of the balls off. The question whether he had or had not the right to do that was very nice, and might have been a rich one for the lawyers.

The Ball engine was brought out in 1883, and the first one shown at the Mechanics' Institute Fair in Boston in the fall of 1883. The Ball governor was not only a shaft governor, but was also fitted with a band-wheel loose on the shaft, which acted to turn on more steam as the load increased. This was abandoned later for another form, and still later for another.

The governor which weighs the load and the inertia governor deal with a variation on steam pressure precisely as others, and as all meet all reasonable demands, then the most simple, reliable, durable and easiest of adjustment is to be preferred.

Many concerns building similar engines have come into existence since 1883, and many gone out,—too many to schedule in this paper.

COMPLETION OF THE NILE DAMS

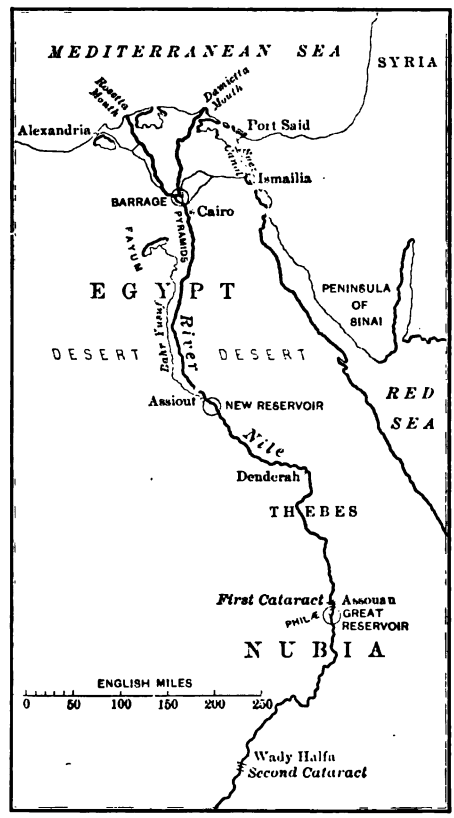
By John Ward, F. S. A.

THE greatest engineering work of our time has been successfully completed, the " High Niles," when they come, will be impounded, and the precious flood will no longer be allowed to waste its sweet waters in the briny Mediterranean. We say when the floods come advisedly, for, strange to tell, the Nile failed to rise last year. In fact, the Nile was lower than ever recorded before, at the very time the expected " High Nile " should have been at its maximum. But there is no great cause for alarm; these failures have often occurred before.

Joseph got his opportunity through one of the seasons of famine which seem to have afflicted Egypt in ancient times as well as modern. Seven years of low Nile and consequent famine were recorded a thousand years before the days of the patriarch Joseph, and the Arab historians of the Christian era mention many such failures of the old river's water supplies. It seems, from the various registers of the various Nilometers for the past century, that the low Niles occur every twelve or thirteen years. They must arise from a failure of rain in the tropics, and likewise the temporary absence of snow on the mountains of Abyssinia and Uganda, many of the great river's tributaries being supplied by the melting of the snows and glaciers of the Equatorial Alps. There is no reason to doubt that the rains and snows will come again; but meanwhile the Assouan dam will have no supply waters to impound in the year of its completion, and the ceremony of its inauguration will be shorn of much of its interest and picturesque effect.

Not so the subsidiary dam of Assiout, all of the sluices of which have been shut for months past, so that the river has been partially impounded and all the great canals deriving their waters above it have been well filled. Mr. Webb, the energetic director-general of reservoirs, no sooner saw that " Old Hapi " was going to withhold supplies than he had all the sluices closed. The crops of Lower Egypt and the Delta have thus all been assured by the service of the Assiout dam. Had there not been this agency there would have been the loss of nearly all the crops,—a loss to be counted by millions sterling.

The British engineers on a former occasion did a great service to the coun-



A VIEW OF THE ASSOUAN DAM, SHOWING THE RESERVOIR BEING FILLED AND THE SLUICES PASSING WATER REQUIRED FOR NAVIGATION AND FOR IRRIGATING LOWER EGYPT

try in making the Delta barrage do its work. The underpinning and concrete floors given to the old structure cost half a million, which was all repaid within three years by the increased revenue from the lands brought into cultivation in the Delta. But the gain to the country from the huge weir at Assiout is vastly greater in comparison, and the utility of the present works is already proved. They were designed to pass out the waste of waters of high

structures were dilated upon and illustrated, though now that the work is finished it is hard to realise the obstacles that were overcome in both cases. The Assouan dam now seems a strong, compact granite weir. It looks smaller than it actually is, and in no way tells the tale of the superhuman exertions called forth in its construction.

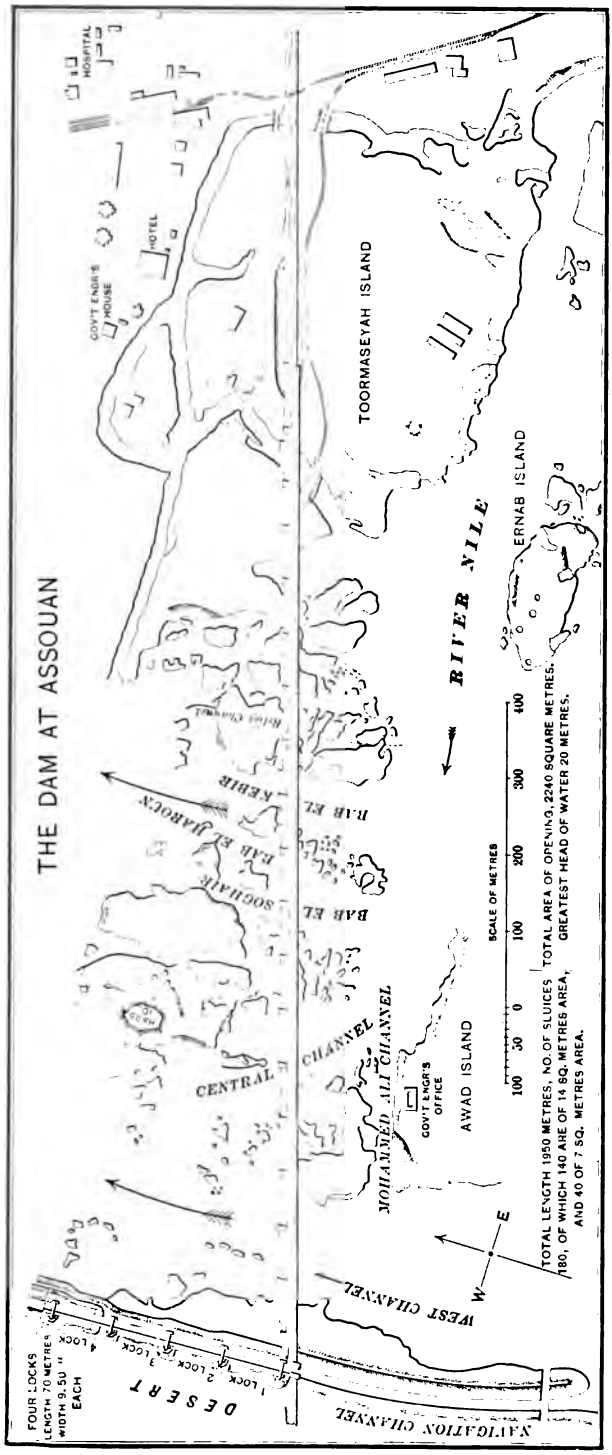
Had the Nile last year reached the high level expected on the south side the utility of the huge wall would have

THE TOP OF THE ASSOUAN DAM, SHOWING THE SLUICE-CONTROLLING MACHINERY

Nile, but they have acted wondrously to save the country at a time when there is no surplus water whatever.

In CASSIER'S MAGAZINE for August and December, 1901, sketches of the history of the Nile barrages were given, with maps and illustrations of the progress of the weirs at Assouan and Assiout, and to these it may be worth while to refer at this time as a matter of further interest. Three of the maps have been reprinted here. The difficulties in getting secure foundations for the huge

been more apparent. Let us hope that the mysterious river may return to its wonted behaviour and that we have seen the last of the "lean years." Joseph had seven lean and seven prosperous years, but then the famine was on "all the world." To compare that state with the present, it would be as if rains had failed simultaneously in America, India, and Australia,—all the world of to-day is of much wider extent than when Egypt was the universal granary. But we must hope that 1903 will see the



Nile dams full to overflowing and usher in a series of "fat years."

Had we seen the great pyramids under construction, had photographs been taken at intervals of the quarrying and transportation of the huge blocks of stone from the quarries, and of the primitive machinery employed to lift them to their places, and had these and the engineers' plans been preserved for us, we would no doubt have had a much greater respect for their work. Seeing simply the complete thing, we scarcely wonder at it; we take the vastness for granted. In the same way the Nile engineering works will soon be regarded as almost commonplace, and no more wonderful than the pyramids themselves.

The huge granite barrier at Assouan has yet had no wide sea of waters to impound, and thus does not show its magnitude. The Nile scarcely shows itself to the north; no water flows from the lower sluice openings; and the higher ones seem a mockery. The island of Philæ, a mile to the south, is still safe, at least till the high Nile comes again. But with the equatorial rains and the melted snows of Abyssinia and Uganda once more in evidence, the promised new African lake will rapidly materialise. But there is one portion of the great work which is almost complete and which will be of much service. The cataract has

BOATS PASSING THROUGH ONE OF THE LOCKS OF THE NAVIGATION CANAL AT THE ASSOUAN DAM

been hitherto an insurmountable barrier to trade by the river. It was only at the very highest Nile that dahabiehs, or trading boats, could be taken up the river towards Nubia, and then at great expense and risk. Now the canal, with its four locks, will allow the largest vessels on the river to ascend or descend with ease without removing any of their cargo. Formerly steamers had to be built in sections and carried round or else held up by the brute force of several hundred men on top of the Nile's highest tide, at the risk of being wrecked in the process.

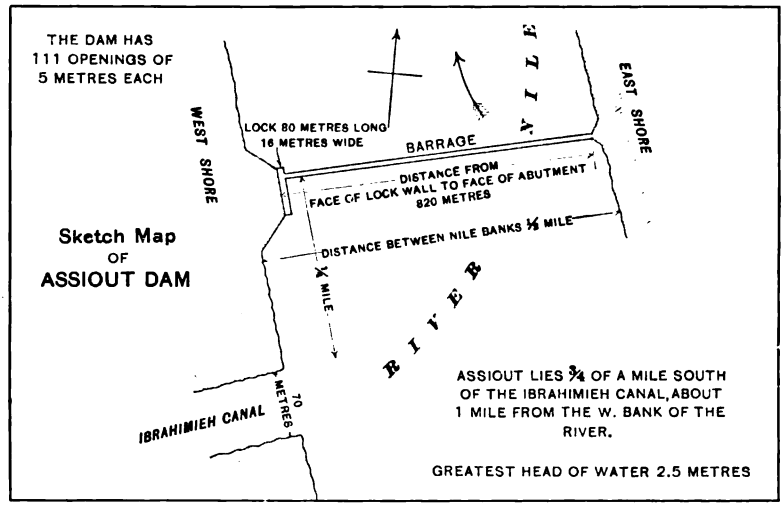
There are four locks, and there had to be a new system of lock-gate specially invented for the purpose. The waters of the Nile, when dammed up, will be all the more likely to deposit mud on the sills of the gates. Ordinary lock-gates or caissons would be unsuitable, as they would not, in this event, keep water-tight. Besides, when the dam is full, the pressure of the enormous mass of water would make any ordinary gate unmanageable.

A new system was, therefore, devised. This comprises a great beam of steel, poised upon the bank and counterbalanced so as to be readily lifted to a vertical position, and as easily dropped transversely across the top of a recess on the opposite side. The beam is fitted with guide rods on the lower side, on which the grooved wheels which suspend the gate act. When the gate is open the huge beams stand vertically at the side of the lock, as shown in the lower illustration on page 556. The gate, or shutter, suspended from its rollers, is run into the recess provided for it, and is always ready for use in its proper vertical position. When it is necessary to close the lock the huge beam is dropped down to its horizontal position and the great gate is moved out to the slot on the side opposite to its recess, the beam forming a steady guide to the wheels and rods from which it hangs. All

A PORTION OF THE COMPLETED ASSIOUT DAM

these movements are executed by hydraulic power, easily controlled by valves and levers. When the gate is closed, the pressure of the water makes it perfectly water-tight. There are five of these gates, all working on the same principle. In the illustrations on page 556, the beams are shown in both vertical and horizontal positions, and the position of the recesses for the shutter-gates can be easily understood. The ease with which these huge masses of steel can be raised and lowered and moved from their hiding places to their fixed position on the opposite bank is nothing short of marvellous.

When the writer visited the Assouan works in February last the first of the great counterpoised beams was being fitted to its place, and when Mr. May, the engineer-in-chief, explained to him the whole working of this ingenious contrivance he was struck with amazement at the perfection of skill which could design and carry out, on such an enormous scale, the first example of an entirely



new invention. The locks are 30 feet wide, and everything has to be of the most perfect construction and at the same time simple in its working, as all the ironwork had to be made in Great Britain, and no repairs are possible on the spot should any serious accident occur. In addition, it is to be remembered that when the canal and dam are in regular service, those in charge of their operation will be natives, not skilled engineers.

THE DOWN-STREAM SIDE OF THE ASSOUAN DAM, SHOWING WATER POURING THROUGH THE SLUICES

The canal has already been doing good work. Many vessels, laden with goods for Halpor and beyond, have made the passage at the spot where the terrors of the cataract had previously prevented all traffic. But there are still the rapids below, which the Arabs will exhibit to future tourists, though the office of " Sheikh of the Cataracts " has ceased to exist.

I need not allude to the working of the Stoney sluices in the dam. These were fully explained in one of the previous articles in this magazine. There are trolley lines of rail and neat little carriages on the top of the dam. When Lord Kitchener visited the work on his visit to Khartoum in November, 1901, these were called into use for the first important time. Those who have seen the old barrage near Cairo can testify to the pleasure of being whirled along by these comfortable little perambulators, but with the weird scenery around and at the great elevation of the Assouan roadway the sensation must be as exhilarating as an aerial voyage.

The Assiout dam was finished nearly a year before its appointed time. The zeal which hurried on the work proves how unselfish were the men superintending it. For this meant, in many cases, the termination of their employment. The country, however, owes much to

A GATE IN ONE OF THE CANAL LOCKS AT THE ASSOUAN DAM

ONE OF THE LOCK GATES IS HERE SHOWN OPEN. THE MANNER OF OPERATION IS DESCRIBED ON PAGE 553

these men, for, the dam being completed, the sluices were set, the precious water was impounded during the summer of 1902, and the result has been that the country has been saved the loss of several millions of pounds sterling.

South of the Assiout dam the mouth of the great Ibrahimieh Canal, shown on the map on page 554, has been blocked with a similar dam of nine openings. There is also a lock and gates for the internal traffic of this waterway. These regulate the supplies of the vast district as far as the Fayum and give the fertilising flood to the ancient Bahr Yusup, the water of Joseph.

There is only one lock for the passage of merchandise in the Assiout dam. It has the ordinary canal gates. We made use of it when the dahabieh, by which I was travelling (the longest on the Nile), went up the Nile during the winter of 1901-1902. The work of opening and closing the gates was done entirely by the native employees of the irrigation department, and was thoroughly and quietly carried out, everything working perfectly. The sluices of the Assiout dam are of the ordinary pattern in use at the Delta barrage. The height of water being only 12 feet at the maximum, this rather old-fashioned apparatus seems to suit the purpose very well. Rails and trolleys are provided also for the convenience of the working of the sluices, and will also form an easy means of communication with the opposite bank of the river, where there are many populous and industrious villages and an enormous traffic on market days in Assiout.

The selection of this part of the river for this great work will be of immense value to the town of Assiout, which has already improved greatly. The Copts, the Christian descendants of the ancient Egyptians, are a power in this district, and from their superior intelligence and industry are taking advantage of the occasion to build a new quarter near the river, where many handsome villas are rising up surrounded by well-planted grounds. A boulevard, lined with trees, extends along the river for a mile or more. The town is managed by a local committèe of the chief inhabitants, and is the best-kept in Egypt. The streets of the new quarter are wide and will be lighted electrically.

The large sums spent in the neighbourhood, owing to the great work going on for three years, have done much for the contented and industrious native inhabitants of Assiout, and, thanks to this condition, the town now has fair hotels, and is becoming a noted place of call for Nile tourists.

In this magazine for August, 1901, portraits were given of the principal engineers connected with this important work. Mr. Maurice Fitzmaurice, chief engineer of the Assouan dam, has been appointed engineer to the London County Council, and Mr. C. R. May was appointed to his place. Mr. G. H. Stephens, chief engineer of the Assiout works, has the credit of completing the works long before the promised time, thus rendering an immense service to the country, and a saving enough to repay a great part of the cost of the undertaking. Mr. William Willcocks, the originator of the whole scheme, must look with pleasure on the realisation of a great part of his plans for the regeneration of the agriculture of Egypt.

A REMEDY FOR STRIKES

INVESTIGATION AND PUBLICITY AS OPPOSED TO COMPULSORY ARBITRATION

By Charles Francis Adams

Mr. Adams' proposed solution of the labour problem, as presented in the following pages, is, as he explains in one of the introductory paragraphs, designed purely for American conditions,—to meet what appear to be the requirements in the United States to-day. Still, it might readily be given a wider application, modified to suit conditions in other countries as well; hence, the likelihood that it will command general interest.—THE EDITOR.

MORE than a year ago, during the great American steel strike of August, 1901, the writer prepared a communication setting forth certain Massachusetts experiences, during previous similar troubles, as being worthy of consideration. They suggested a possible solution, practical in character, of what are known as "labour troubles," —the conflicts between employer and employee which result in strikes and tie-ups. Printed in various papers, this communication caused at the time some discussion. More recently the writer has been applying the experience then set forth, and the principles advocated, to the existing and more serious complications which have since arisen. He has also been in communication with Colonel Carroll D. Wright and Mr. Henry Cabot Lodge, one of the Senators from Massachusetts, discussing the facts and theories involved, with a view to what may be considered an outcome based on the systems, political and constitutional, as well as the labour conditions, and the social and industrial organisations, existing to-day in the United States. With a view to ultimate satisfactory results, the effort has been to recognise facts, and to make action conform to them. The writer's purpose in what follows, originally presented for consideration to the National Civic Federation at its last annual meeting, is to set forth as briefly as possible the conclusions so far reached.

In the communication referred to the writer first called attention to the nearest approach to a practical solution of the labour problem in accordance with American conditions, ideals and traditions, which has, so far as he knows, yet been devised and put in use. And, in making this statement I lay emphasis upon the word "American"; for I hold it to be quite useless to take a system, whether purely ideal and theoretical, or even, in other countries, practicable, and apply it generally. The first essential to success in constructing or developing any system of laws is that such system shall be in conformity with the conditions, ideals and traditions of the community for which it is designed. To ignore them, much more to run counter to them, is to court failure at the outset. As Alexander Hamilton said more than a century ago of the United States Constitution,—"A government must be fitted to a nation much as a coat to the individual, and consequently what may be good at Philadelphia may be bad at Paris, and ridiculed at Petersburg." In like manner a system of legislation designed to regulate the relations of labour and capital may

work well in Australia; but it by no means follows that a similar system would work well in Great Britain or Germany, and a system which might be practical, if not reasonably satisfactory, in Bohemia and Austro-Hungary would almost surely prove quite otherwise in the United States.

This, I am well aware, is a commonplace, almost, indeed, a platitude. And yet it is necessary to premise it carefully; for, just so long as men are what they now are, unusual exigencies will, under any system of government, from time to time arise; but, when such do arise, it is always very noticeable how the air is at once filled with suggestions of remedy, either quite untried or borrowed from other lands. And such are recommended for immediate adoption, wholly regardless of our constitution, laws, political organisation or the spirit of our industrial development. This is empirical; and, in these matters, empiricism is of all things to be shunned.

I come now to the experience I have referred to. There is, in the State of Massachusetts, and has been for over thirty years, a Board of Railroad Commissioners. In the history of that board there was one important but now quite forgotten, incident, from which a highly suggestive lesson may be drawn. It occurred twenty-five years ago. The Massachusetts Railroad Commission was organised on the theory that, in adjusting matters of difference between the community and its railroad corporations, the vesting of arbitrary power in such a tribunal was a hindrance to it rather than a help; for the reason that in America force is in the long run less effective in producing results than investigation, and subsequent well-considered recommendations based thereon. The appeal was in every case to be made to reason and public opinion, and not to the sheriff or the soldier.

Accordingly, in the event of differences between the corporations and their employees, even those resulting in strikes and tie-ups, the Commissioners had no executive power. It was their duty, in a general way, to take official cognisance of the fact when the community was sustaining an injury or an inconvenience, and to investigate the causes thereof. Having so investigated, the board was empowered to locate the responsibility for the injury and inconvenience, and to make its recommendations accordingly; but those recommendations had merely a moral force. They could be addressed to the parties concerned and to public opinion only. Their effect, greater or less, was measured by the justice and good sense impressed upon them. The Commissioners, moreover, disavowed any wish to be clothed with larger powers. They feared the possession of such powers. They were persuaded that they could, in the end, accomplish more satisfactory results without them.

This theory was soon put to a test. At four o'clock in the afternoon of the twelfth of February, 1877, all the locomotive engineers and firemen in the employ of the Boston & Maine Railroad Company stopped work in a body, abandoning their trains. The move was not altogether unexpected, but the operation of the road was seriously interfered with. The Commissioners did not at first intervene, neither party calling upon them. Indeed, both parties were unwilling so to do, for each was apprehensive, apparently, of adverse action. During several days, accordingly, the Commissioners preserved an attitude of silent observation. After the lapse of a reasonable period, however, the board concluded that it was plainly time to recognise the fact that the public was suffering serious inconvenience; for then the Boston & Maine Railroad was, as it still is, one of the principal arteries of Eastern New England.

The president and directors of the company and the employees of the Brotherhood of Locomotive Engineers were accordingly notified that the board proposed to take a hand in the business. This it proceeded to do. An immediate investigation was notified. Both parties appeared,—for, without confessing itself in the wrong, neither party could well help so doing,—and professed a perfect willingness to submit their cases. No suggestion of a readi-

ness to abide by any decision that might be given thereon was either asked for or given; but the board proceeded to hear witnesses and to elicit the facts.

The inquiry was continued through three days, and, on the twenty-first of February, the report of the board was made public, appearing in full in all the newspapers of that date. In it the Commissioners, after carefully and judiciously sifting out the essential facts from the evidence submitted, placed the responsibility for the trouble where the weight of evidence showed it belonged, and thereupon proceeded to make such recommendations as in its judgment the exigencies called for. The effect was immediate. An authentic record was before the community, and public opinion, crystallising, made itself decisively felt. It is not necessary to enter further into the history and merits,—the rights and the wrongs,—of that particular struggle. My object is merely to call attention to what was then done, and done successfully, as constituting the nearest practical approach consistent with the American political and social system to what is known as "Compulsory Arbitration." It was compulsory inquiry only, and an appeal thereon to the reason and sense of right of all concerned. Reliance was placed in an enlightened sense of right of all concerned and an informed public opinion.

Here, then, is a system. Under it a public tribunal is provided; that tribunal takes official cognisance of what is notorious, and, when either the peace or the business of the community sustains prejudice or is gravely jeopardised, it becomes its duty to intervene. It intervenes only for the purpose of obtaining the information necessary to enable it to form a clear, judicial opinion. It then sets the facts before the community and makes its recommendations. It locates responsibility. There it stops; for it can compel obedience on neither side.

Now, let us apply this proposed system to the conditions which, during the past year, have existed in the Pennsylvania anthracite region. Let us assume that provision by law existed under which the Executive, either national or State, was empowered and directed to appoint such a board *pro hac vice*, calling it into existence to meet a sudden emergency. The chances, I submit, are at least nine out of ten that, if such a machinery had existed, and had been judiciously employed either by the Governor of Pennsylvania or the President of the United States, a practical solution of the difficulty which for over eight months has harassed the country would have been reached.

The community began to sustain grave prejudice at an early stage of the troubles. The resulting injury became more and more flagrant as the weeks passed by. The continuance of such conditions not only was injurious to private interests, but the public peace itself was involved. Under such circumstances experience shows that neither party will, for obvious reasons, voluntarily call upon a board or commission to intervene, for such action is tantamount to a confession of weakness. Both will look at it askance. It must rest, therefore, in the discretion of the Executive to decide whether a case has arisen which calls for public initiative, the public being a third party to the controversy. That it is such it is impossible to deny. It, therefore, has rights and interests,—a standing in court. It having been decided, in the exercise of a sound discretion, that circumstances call for this third party to act, the Executive gives notice to all concerned that, at the proper time and place, it is proposed to enter upon an investigation. If both parties see fit then to appear and submit evidence as to the facts, that evidence becomes public property. If one party appears, the other absents itself at its peril. Should neither party appear, producing authentic documents and putting in a case, the board would proceed to enlighten itself through all other accessible means. In behalf of the third party to the controversy, of which it is the representative, it should be empowered to summon witnesses and to enforce the production of documents.

Having completed its investigation,

it would then make its recommendations definitely, and, if it knows its business, concisely locating responsibility where the evidence shows it belongs. A practical solution of the trouble, such as would naturally commend itself to the judgment of an unprejudiced tribunal, would be pointed out. A solution of that sort always exists. This report would be transmitted to the appointing power, whether President or Governor. By him it would then be communicated to the parties in interest, including the public; and, in due time, submitted to Congress, or the State Legislature, always with such enforcing or qualifying recommendations as might commend themselves to executive judgment.

The report so made would carry with the public and with the parties concerned exactly that degree of weight which its judicial character and reasoning might impart to it,—that, and nothing more. It could not be enforced by any governmental process. There would be neither sheriff, nor *posse comitatus*, nor military force behind it. But, if well reasoned and impartial, it would bring to bear the moral weight of an enlightened public opinion.

Did such a machinery as this exist, simple and advisory only, it is not unsafe to say that it would prove adequate for the settlement of nine complications out of ten. In the case of the Pennsylvania anthracite strike, for instance, if the Commission since appointed by President Roosevelt could have been appointed four months sooner, while the conflict was in the earlier stage of development, its report would have afforded to one or both parties concerned an opportunity to withdraw creditably from a position which afterwards, for at least one of them, became false and consequently perilous.

What the country has needed is light,—the possession, if not of undisputed facts, at least of an authentic statement of the facts in dispute. Had these been spread upon the record and submitted for public consideration, it could hardly be otherwise than that recommendations firm, judicious and reasonable based thereon would have sufficed to remove from the path the impediment of false pride,—that stumbling block in the case of nine strikes out of ten. An opportunity of gracefully receding would have been offered to one or both parties concerned. Should either party have then insisted, in the face of light and reason, the responsibility for obstinate insistence would have been upon its head.

In the United States public opinion has in such cases a very summary, as well as effective, way of enforcing its own process. An excellent and sufficient example of this was furnished in the sudden change of front on the part of one of the parties to the present anthracite complication, executed in the face of a rapidly rising popular sentiment. Persistence was felt to involve too much risk. It would be so in the great mass of these cases. They are preventible. What is wanted for their prevention is not force, but light and guidance.

This generally acknowledged fact to the contrary notwithstanding, it is singular to note, when any controversy arises, how such a method of settlement as that here proposed is at once set aside as being inadequate and unworthy of consideration, because behind it there is no constable's club or soldier's bayonet. In fact, however, the word "compulsion" has an unpleasant sound. In theory only is the thing itself popular. With us the final appeal must always be to reason, and public opinion enforces the edict of that appeal. In every field of legislation this has been again and again illustrated, and yet the appeal to reason, as now here made, is almost as invariably as contemptuously dismissed from consideration on the ground that there is behind it no force to compel obedience.

It is this tendency to compulsion against which, I submit, it is the especial function of the Civic Federation* to protest. We should lay emphasis on the fact that our appeal is to reason and

*The National Civic Federation is an association of thirty-six leading representatives of American labour, capital, and the general public, the object of which is to prevent strikes and lockouts by bringing the contending parties together at a conference, to talk their differences out before matters have reached an acute stage.

not to force. The difficulty with the Federation is not want of power, but want of official standing. It is a volunteer. At no time, for instance, during the last six months could it enter the field as representing the Executive of either State or Nation; and had it entered the field on its own initiative only, it would have been in imminent danger of incurring the contempt not only of both parties to the controversy, but of the public itself. It has, therefore, been compelled to inaction,—a purely waiting attitude. This fact in itself discloses a want. A piece of machinery is lacking.

But it is argued that such boards already exist, and the results of their efforts have not proved satisfactory. This assumption I deny, and on broad grounds. When such large interests are involved as, for instance, in the recent strike in the Pennsylvania anthracite region, represented by men of capacity on each side, to deal effectively it would be necessary for the community to have the power of availing itself of the services of the very best men, and those of the highest character and authority at its command. If it speaks at all, it should speak adequately.

If last June it had been the duty, as well as within the power, of the President, or of the Governor of Pennsylvania, recognising that the public interests and convenience were involved and that lasting injuries might be entailed, to take cognisance of the situation in the anthracite region, it should, under the system proposed, have been the duty of either Executive to call upon the very strongest men in the community,—those of highest character and most intimately acquainted with every condition involved. No man in the country so called upon could have refused to serve; yet such men will not accept, nor should they be expected to accept, merely salaried positions, permanent in character, on a board of subordinate importance.

The machinery now suggested should, moreover, be reserved, and brought into action only in special exigencies. It is not designed, nor is it adapted, to every-day use. In that field the existing boards are doing good service, and doing it sufficiently well; but, for obvious reasons, they are not equal to the exceptional occasions. They occupy the positions of municipal courts; but, where grave problems of constitutional law present themselves, such are not referred to police magistrates for decision, nor would the decision of those magistrates, if rendered upon them, carry the necessary weight.

Exceptional cases can only be dealt with exceptionally. Fortunately they do not arise often. But they unquestionably will recur periodically in the future; and, when they come, their presence is unmistakable. It would then be for the Executive, State or National, to take cognisance of what is apparent, and to set in motion the special machinery designed and held in reserve for that exigency.

It is equally futile to say that the parties concerned, unconsenting thereto, might decline to appear before such a Commission. In such case the Commission would simply proceed with its inquiry in the absence of such party or parties. With the power of summoning witnesses and compelling the production of books all necessary information would be accessible to it. But the parties could not refuse to appear. They would not dare to refuse.

Finally, the report of such a tribunal, addressed to its appointing power, would be like the decision of a high court of justice on an abstract point of constitutional law of the first magnitude. Read by every one, if the decision were weak, or bore in it signs of prejudice or interest, it would, falling dead, fail to influence public opinion. Equally, if handled with a firm and intelligent grasp, it would carry conviction. That conviction, when so carried, is in this country irresistible. In the end it makes opposition confessedly factious.

The trouble with us is that we are always prating of the force of public opinion; but, when the exigency arises, we evince no confidence whatever in it. Like a parcel of children, we are apt to cry out for the master to come in and

enforce instant obedience with the rod. I submit that permanent results with us in America are not reached in that way. Let us in this matter have the courage of our convictions.

I have already expressed my belief that, if such a system as I have here suggested could be brought into being through a very simple act of legislation, which, open to no constitutional or other objection, would be in entire accord with our industrial system, our traditions and the American ideals, it would settle nine matters of controversy out of ten which arise. I now further submit, it is highly desirable from every point of view that the tenth case of controversy should not be settled, but should be fought out.

In the practical affairs of life, as we all know, it is necessary now and then that the fight should be to a finish. The American Civil War was a case in point. No arbitration ever could have settled that; no appeal to reason would have produced conviction. The issue had to be fought to the bitter end. That it was so fought we are now all grateful, though at the time the demand was loud and incessant for some compromise,—any close to the "useless, the suicidal strife." This exceptional case, however, by no means brought the principles of arbitration and reasonable adjustment into discredit and consequent disuse. On the contrary, they have grown stronger ever since, securing more and more hold on public opinion.

What is necessary, in my judgment, is to organise that public opinion, and, when organised and made effective, to rely on it to produce all desirable results in the average case. But it can be organised only by bringing it to bear through the medium of capable men, thoroughly informed upon the special matter under discussion, and competent to express courageous opinions clearly. The tribunal doing this should then dissolve. It should not continue in existence, the target for criticism, partisan discussion and popular odium. Should a new case arise, another tribunal of a similar character would at the proper time be called into being to deal with it in its turn.

Sound and fruitful legislation cannot, moreover, be improvised. It is idle to talk in language as empty as it is grandiose of "curbing," or regulating by any patented method, potentates and power of such large, and yet vague, character as those that labour and capital are now continually bringing into the field. A governmental regulation which shall deal satisfactorily with them must rest upon a broad and well-considered basis of experience. It would be the natural outcome of a series of reports of tribunals such as that suggested.

It is equally futile to suppose that this labour contest in which we have been engaged, and of which we have so long experienced the inconvenient results, is going to be settled in a day or an hour, or next year, or within the next ten years. It will continue with us during the remainder of our lives, and with our children after us; but we will slowly and tentatively approximate to satisfactory results. Under these circumstances if a solution, represented by a proper legislative and administrative machinery, is ever to be evolved, it must be evolved from a series of wearisome investigations and reports thereon.

In the case of the national executive, some question has been raised as to its functions and powers, in view of our constitutional system and the reserved rights of the States. I cannot, however, see that this enters into the present question, or what is now proposed. It is certainly the duty of the President to inform himself upon all questions relating to the carriage of the mails, and to the movement of commerce, whether foreign or interstate. Questions of revenue are involved; questions affecting the transportation of material, men and supplies may be involved. To inform himself, he should be empowered to appoint agencies competent to investigate and report thereon. It is not now proposed to clothe him with any power in these exigencies, except that of receiving a report, forwarding it to the parties involved, together with his own recommendations, and then sub-

mitting the same to Congress. To give the President power to intervene by any executive act of a compulsory character would, in my opinion, jeopardise at the beginning every desirable ultimate result of the experiment proposed. Congressional action is always in reserve; but even Congressional action ought to be intelligent, and, to be intelligent, it should be well considered,—based on a considerable body of facts, judicially ascertained. The judicial ascertainment of facts and the study of principles involved therein is, therefore, what the occasion immediately demands. Sound remedial legislation will in due time result therefrom. But at present the chances are enormous that crude and precipitate effort at a compulsory betterment of existing conditions would only make what is already quite sufficiently bad distinctly worse.

As the result of my conversations with Colonel Wright and Mr. Lodge, I have undertaken to draw up a simple Act, in few sections, based upon the foregoing principles and looking to the results indicated. It could be passed *mutatis mutandis*, by any State Legislature or by Congress. It would contravene no constitutional provision or private right, but simply secure to the community,—the third party involved in every controversy of this sort of any magnitude,—the right to get at the facts in dispute, and, after so doing, to bring to bear an intelligent pressure of its own, looking to a reasonable solution of troubles sure, hereafter, to arise. Such an Act has accordingly been prepared, and is subjoined hereto.

AN ACT TO PROVIDE FOR THE INVESTIGATION OF CONTROVERSIES AFFECTING INTERSTATE COMMERCE AND FOR OTHER PURPOSES.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled:

Section 1. That whenever within any State or States, Territory or Territories of the United States a controversy concerning wages, hours of labour or conditions of emplyment shall arise between an employer being an individual, partnership, association, corporation or other combination, and the employees or association or combination of employees of such employer, by reason of which controversy the transportation of the United States mails, the operations, civil or military, of the Government of the United States, or the free and regular movement of commerce among the several States and with foreign nations is, in the judgment of the President, interrupted or directly affected, or threatened with being so interrupted or directly affected, the President shall in his discretion inquire into the same and investigate the causes thereof.

Sec. 2. To this end the President may appoint a special Commission, not exceeding seven in number, of persons in his judgment specially qualified to conduct such an investigation.

Sec. 3. Such Commission shall organise with all convenient despatch, and upon giving reasonable notice to the parties to the controversy, either at the seat of disturbance or elsewhere as it may deem most expedient, shall proceed to investigate the causes of such controversy and the remedy therefor.

Sec. 4. The parties to the controversy shall be entitled to be present in person or by counsel throughout the continuation of the investigation, and shall be entitled to a hearing thereon, subject always to such rules of procedure as the Commission may adopt; but nothing in this section contained shall be construed as entitling said parties to be present during the proceedings of the Commission prior to or after the completion of their investigation.

Sec. 5. For the purpose of this Act the Commission, or any one Commissioner, shall have power to administer oaths and affirmations, to sign subpœnas, to require the testimony of witnesses either by attendance in person or by deposition, and to require the production of such books, papers, contracts, agreements, and documents as may be deemed material to a just determination of the matters under investigation; and to this end the Commission may invoke the aid of the courts of the United States to compel witnesses to attend and testify

and to produce such books, papers, contracts, agreements, and documents; and for the purposes of this section it shall be vested with the same powers, to the same extent and under the same conditions and penalties, as are vested in the Interstate Commerce Commission by the Act to regulate commerce, approved February 4, 1887, and the Acts amendatory and in addition thereto; and it shall be the duty of the said courts of the United States to render said Commission the same aid to the same extent and under the same conditions as is provided by said Acts in aid of said Interstate Commerce Commission; and witnesses examined as aforesaid shall be subject to the same duties and entitled to the same immunities as is provided in said Acts.

Sec. 6. For the purposes of this Act the Commission may, whenever it deems it expedient, enter and inspect any public institution, factory, workshop, or mine, and may employ one or more competent experts to examine accounts, books or official reports, or to examine and report on any matter, material to the investigation, in which such examination and report may be deemed of substantial assistance.

Sec. 7. Having made such investigation and elicited such information of all the facts connected with the controversy into which they were appointed to inquire, the Commission shall formulate its report thereon, setting forth the causes of the same, locating so far as may be the responsibility therefor, and making such specific recommendations as shall in its judgment put an end to such controversy or disturbance and prevent a recurrence thereof, suggesting any legislation which the case may seem to require.

Sec. 8. The report of such Commission shall forthwith be transmitted to the President and by him communicated, together with such portions of the evidence elicited and any comments of further recommendation he may see fit to make, to the principal parties responsible for the controversy or involved therein; and the papers shall be duly transmitted to Congress for its information and action.

Sec. 9. The Commission may, from time to time, make or amend such general rules or orders as may be deemed appropriate for the order and regulation of its investigations and proceedings, including forms of notices and the service thereof, which shall conform as nearly as may be to those in use in the courts of the United States.

Sec. 10. The President is authorised and empowered to fix a reasonable compensation to be paid to the members of the Commission from the Treasury at such times and in such manner as he shall direct. The Commission shall have authority to employ and fix the compensation of such employees as it may find necessary to the proper performance of his duties, subject to the approval of the Secretary of the Interior.

The Commission shall be furnished by the Secretary of the Interior with suitable offices and all necessary office supplies. Witnesses summoned before the Commission shall be paid the same fees and mileage that are paid to witnesses in the courts of the United States.

All of the expenses of the Commission, including all necessary expenses for transportation incurred by the Commissioners or by their employees under their orders, in making any investigation under this Act, shall be allowed and paid, on the presentation of itemised vouchers therefor approved by the chairman of the Commission and the Secretary of the Interior.

Sec. 11. No Commission appointed under this Act shall continue for a period of over three months from the date of the appointment thereof, unless at any time before the expiration of such period the President shall otherwise order.

POWER FROM THE INTERIOR HEAT OF THE EARTH

By William Hallock

NATURE'S PENT-UP ENERGY HERE FINDS AN OUTLET

"COME! The time is almost up; let us see it once more."

Standing upon the slightly rising ground one watches the low, conical crater, and notices the violent "bumping" beneath his feet, which increases in intensity until it seems as if the crust must give way. Then from the narrow crack of an opening there splashes out a quantity of boiling water; then another; when, suddenly, with a deafening roar, never to be forgotten, there arises before one's eyes a seething column of water, several feet in cross-section, to a height of one hundred, one hundred and twenty, one hundred and fifty feet, towering aloft like some gigantic boiling fountain. The steam drifts away in mighty clouds, and the waters fall in torrents. Five minutes, and all is over, to be repeated after a lapse of an hour.

Such, in brief, is an eruption of the "Old Faithful" Geyser in the Upper Firehole Basin of the Yellowstone National Park. No one can witness such an exhibition without being impressed with the enormous power involved in the display. Hundreds have asked what horse-power would be required to duplicate the spectacle. In the near future a report of the work in that region by the United States Geological Survey, under Mr. Arnold Hague, will give details as to the estimated energy involved. If we include the heating of the water, as well as the projecting of it to these heights, not far from 100,000 horse-power would be necessary to duplicate an eruption of this typical geyser.

It would be impossible for anyone to spend a few weeks studying the phenomena that may be observed in any of the geyser basins of the world without being impressed with the enormous waste of energy which is going on there. In 1886 and the preceding summers it was the writer's good fortune to spend a considerable amount of time in the geyser basins of the Yellowstone National Park, and it would be strange if one could behold an eruption like that of "Old Faithful" without being impressed with the enormous energy involved; but, of course, a large part of the time the geyser is quiet, and requires comparatively little heat energy.

It is very probable that the depths to which it would be necessary to drill, in a region like the Yellowstone National Park, in order to reach a temperature of boiling water would not be great. In fact, everything points to the conclusion that the seat of energy involved in the operations in the Yellowstone Park is probably within one mile of the surface.

If we consider the amount of energy brought to the surface in the form of hot water from all the hot springs, we should certainly reach very large figures, and this energy, although not available for operating an ordinary steam engine, might be utilised perfectly well for operating an engine which used some liquid like ether, alcohol, or car-

"OLD FAITHFUL" IN YELLOWSTONE PARK, U. S. A., BEFORE ERUPTION

bonic acid gas, boiling at a temperature considerably below the temperature of the water in the hot springs. In fact, to make a specific application, why would it not be practicable to place the boiler of an ether engine in the gigantic pool of boiling water at "Hell's Half Acre" and use the cold water of the Firehole River for the condenser, and who knows but that we may some day see this done, and the power utilised to run a trolley line through the Park? We should have, in this case, a range of temperature from about 195° for the boiler to 50° for the condenser, and it is perfectly practicable to work an engine between these limits. The supply of hot water is apparently inexhaustible.

The suggestion for utilising the heat below the surface of the earth has been a favourite one, and has reappeared at every recurrence of interest in underground temperatures. In 1897, when a very deep hole at Pittsburgh was completed and temperature observations were made in it, the suggestion appeared again, and was rather elaborately exploited at the time.

It is comparatively easy to compute the depth to which it would be necessary to penetrate in order to find temperatures that would be suitable for the operations with the ordinary steam en-

"OLD FAITHFUL" IN ERUPTION. THE HOT WATER COLUMN TOWERS ALOFT LIKE A GIGANTIC BOILING FOUNTAIN

gine; but in such localities as Pittsburgh the depth would be so considerable as to appear prohibitory, for the present at least. Still, nothing seems to be impossible to modern engineering, and perhaps the next ten years will make a hole 15,000 feet deep as simple a matter as one of 5000 feet is at the present time. Moreover, we are not compelled to select such disadvantageous localities for our enterprise. If, for example, we choose a place where the remnants of volcanic energy are near the surface, it would, undoubtedly, be possible at the present time to put down a hole deep enough to reach a temperature of 300 degrees.

For many years a question of great interest has been the "thermal gradient" of the earth's crust, or, in other words, the number of feet we must penetrate toward the centre of the earth, in order to experience a rise in temperature of one degree. Most of the latest and best values have ranged around 60 feet for one degree Fahrenheit. This rise in temperature should be counted from the temperature at a depth of about 100 feet, where the daily and annual fluctuations of temperature are no longer felt. The temperature of this invariable stratum is about equal to the true mean annual temperature of the locality.

At the deep well at Wheeling, W. Va., this temperature is practically 52° F. The thermal gradient in this well is very suggestive. In the upper part it is about 1° F. for 80 to 90 feet, but in the lower parts it is decidedly greater, and is even above 1° F. for 60 feet. The well is 4500 feet deep, and the temperature at the bottom is about 106° F.

The well at West Elizabeth, near Pittsburgh, is 5580 feet deep, and practically identical with that at Wheeling as regards its temperatures. In some localities the rise in temperature is much slower than at Wheeling, and, again, in places like the old Comstock mine at Virginia City, Nevada, the rise is so rapid that temperatures of 170° are reached in the mine itself. Certainly in the Yellowstone Park, or near Vesuvius or Mt. Pelée, one would find a very rapid increase in temperature. The problem, it appears to the writer, is not so much concerned with the putting down of a hole, or holes, as with the obtaining of a continued and sufficient supply of energy from the rocks beneath, because the moment operations are commenced, and water or any other liquid is introduced into the bottom of the well, the surrounding rocks will immediately be cooled, and must rely upon the outlying areas for a supply of heat by conduction. Thus it would be necessary to start our experiment at a depth where the temperature was perhaps five or six hundred degrees in order that we might ultimately obtain a working temperature of three hundred. These conditions would depend entirely upon the size of the reservoir that we could obtain and upon the heat conductivity of the rock.

It was in order to obtain a reservoir as large as possible and with the most extensive ramifications that the suggestion was made of using two holes and shattering the intervening rock with enormous charges of nitro-glycerine. The larger the surface of our reservoir, the more heat can be obtained from the surrounding rock; and the greater the difference in temperature between the unaffected rock and the working temperature in the reservoir, the more active will be the supply of heat. It is within the domain of our present knowledge to compute for any assumed contents the horse-power we might expect to obtain under normal conditions. The heat conductivity of rock has been carefully studied and is very well known.

For example, if we were to assume that we could shatter a volume of rock about 160 feet in radius, and that we could count upon a final thermal gradient near our reservoir of 1° F. for 6 feet, we could obtain a constant supply of a little over 20 horse-power,—not a very large return for going miles into the heart of the earth. Of course, it might be possible to improve these conditions.

It must be evident that no power would be needed to introduce the water, because its density being so much greater than that of the rising stream of hot

water or steam, the circulation would be established without artificial means. It would be similar to that by means of which the manufacturers of salt obtain their material, by pumping down fresh water into the salt layers and forcing up the saturated solution, thus making the water the vehicle to carry the salt from the interior of the earth to the surface, just as we should use the water to carry the energy to the surface, except that in our case the pumps would be superfluous.

At the present time there is a hole 5580 feet deep near Pittsburgh, and one in Germany over 6600 feet deep. The Pittsburgh hole is of the oil well type, 6 inches in diameter. It might be impracticable at present to increase the depth of that hole to 10,000 feet, but on the shores of Lake Superior there is a mine over 5000 feet deep, and it would certainly not be impracticable to put down a hole from the bottom of that mine an additional depth of 5000 feet, thus obtaining a total penetration of 10,000 feet, and perhaps enabling power enough to be derived to operate a part at least of the mine machinery.

We are apt to lose sight of the fact that we are continually obtaining energy from the interior of the earth by conduction to the surface layers. The heat that comes to the surface has been carefully determined, and it has been estimated that it is sufficient to melt a layer of ice four inches thick every year. This seems like a very small amount; but if we compute the amount of energy reaching the surface of one acre, for example, we should find that it would be somewhere in the neighbourhood of 5 horsepower. Even this is not very much, and is not available by any of the ordinary methods; but still it is there, and when extended over a number of acres will convey perhaps some idea of the inexhaustible supply of heat above which we are living.

When the question of utilising the internal heat of the earth is discussed, it is usually confined to that branch which deals with its use for motive power by evaporating water. Some other liquid, even liquid air, might be used, obviating the high temperatures and great depths; but the slow conduction by the rocks would always prove a great obstacle.

Throughout the Central West of the United States many artesian wells are bringing to the surface enormous quantities of water, all of which is more or less warm; and we might view a coal strike with greater equanimity if we had a ceaseless supply of warm water with which we could at least warm our houses. The trials and extravagance of an Alaskan winter would be materially decreased by a natural warm water heating system. No pumps would be needed, as the cold water going down would be enough heavier than the warm coming up to maintain good circulation.

Three lines of development are open in this field. In the one case a liquid with low boiling point may be used in holes of comparatively slight depth; or water may be employed in special localities near volcanoes or hot springs; or, again, the hot water may be used for heating purposes alone.

In the not distant future we may feel the rigour of the Arctic winter mollified by warming currents from subterranean fires, and see such volcanoes as Mt. Pelée and Vesuvius surrounded with factories which shall draw the fiery venom from these giant serpents and utilise it for the benefit of mankind.

THE RECENT BRITISH TRADES UNION VISIT TO THE UNITED STATES

By Alfred Mosely

Mr. Mosely's remarks in the following pages are supplementary to his earlier ones on the same subject printed in the January number of this magazine, to which it may be interesting to refer at this time. The present article tells more in detail of what was seen during its visit to the United States by what has become known as the Mosely commission, of the men who were part of it, and of its scope and aims, while the earlier article reflected principally Mr. Mosely's own opinions of American employers and employees, their relations and their methods.—THE EDITOR.

I HAVE been asked to give a brief account of the reasons which induced me, towards the close of last year, to take over to the United States a number of British trades unionists on a tour of inspection; to describe something of what the party saw during its visit; and to indicate what results I hope will flow from the expedition.

The reasons which induced me to organise this labour commission were succinctly put by the Prince of Wales when, in the speech he delivered at the Guildhall, London, immediately after his return from his cruise in the *Ophir*, he told Great Britain that she must "wake up." British manufacturers, as it seems to me, have, of late years, been allowing themselves to fall into a state of apathy; they have failed to adapt themselves to changed conditions of demand and to adopt new methods of production such as are being initiated by their competitors for the trade of the world. Sometimes one might almost think that they have scarcely realised that they have competition to face, but rather fancy themselves still in those blissful times when continued wars had so exhausted the energies and resources of Continental Europe that Great Britain was practically the only manufacturing country of the globe. The result has been a slackening of the effort and enterprise which raised her to that proud position, and, comparatively speaking, she has fallen behind in the race. The volume of her manufactures has not, indeed, suffered any absolute diminution; but it has failed to increase, of late years, at anything like the rate attained by other competing countries. That is to say, while exploration and railways and steamships have been adding to the area of the commercial world at an unprecedented rate, Great Britain has failed to expand her trade in the same ratio, in spite of the fact that her pre-eminent position at the beginning of the race gave her a splendid handicap.

In considering the cause of this stagnation and wondering how it might possibly be cured, I came to the conclusion that it was largely due to British adherence to methods of manufacture which have become antiquated and inefficient, this, in turn, being attributable to the more fundamental cause of lack of diffused education. Looking round at the greatest competing nations, Germany and America, I saw in both a higher educational standard, apparently bringing with it greater adaptability and more intelligently applied effort.

This inspired me with the idea of taking out to those countries a commission of picked men to investigate the question and report in concrete terms in what respects British educationalists could take a leaf out of their competitors' books. This commission I had intended to bring out to America last autumn;

but circumstances seemed to render a postponement advisable, and, as at present arranged, its visit will be paid towards the end of this year.

There were also some points connected more particularly with the processes of manufacture,—they might be roughly described as the attitude of employers and workmen towards one another and towards their work,—which, from some experience with American engineers and their work, and from personal observation in the United States, I thought were better managed in America than in Great Britain, and I thought I might do some service if I could introduce from across the Atlantic some tincture of American methods into the practice of my own country. I, therefore, determined to take out a number of British workingmen to the United States so that they might see for themselves how things are done in manufactories there, and at the same time be brought to realise a change of which the full significance is, perhaps, not yet generally appreciated at its true value in the United Kingdom,—the change by which the United States has ceased to be a purely agricultural country and has become also a great manufacturing one, with undeniable claims to her share in the commerce of the world.

But before inviting a party to accompany me to America it became necessary to make certain that they would be able to gain access to the things I wished them to see. Happily there was no difficulty on that score. Armed with introductions kindly given me by the American Ambassador in London, I went over to the United States in March last, and during the six weeks I spent there making the preliminary arrangements I found that these introductions, together with some personal friendships among the members of the American Civic Federation, which, I am glad to say, took a great interest in my enterprise, were sufficient to gain for myself and my party access to practically every factory in the United States we might desire to visit. And here I should like to record my appreciation of the liberality with which the doors were opened to us, the freedom with which our questions were answered, and the welcome which was everywhere extended to us.

This point thus satisfactorily settled, it remained to select the members of my commission. To this end I consulted some of the most eminent authorities on labour and the labour movement in London, so that all those selected should be men whose statements would be regarded as carrying weight and would reach as many others as possible. When the list was drawn up, it contained the names of the best-known and most influential trade unionists in the United Kingdom. When the responses to the invitations were received, it was found that in every case but one they had been accepted; in addition, I received applications on behalf of many other societies which I had not been able to include in my list, asking that their representatives be taken with the expedition.

The following are the names of the delegates, together with those of the organisations by which each was accredited:—H. Crawford, of the Amalgamated Carpenters and Joiners; H. R. Taylor, of the Operative Bricklayers; M. Deller, of the Operative Plasterers; George N. Barnes, of the Amalgamated Society of Engineers; J. Maddison, of the Ironfounders of Great Britain and Ireland; D. C. Cummings, of the Boilermakers and Iron and Steel Shipbuilders; Alexander Wilkie, of the Associated Shipwrights; James Cox, of the Associated Iron and Steel Workers; R. Holmshaw, of the Sheffield Trades; T. Ashton, of the Amalgamated Operative Cotton Spinners; T. A. Flynn, of the Amalgamated Tailors; B. Hornidge, of the National Union of Boot and Shoe Operatives; Harry Ham, of the National Amalgamated Furnishing Trades; G. J. Lapping, of the Amalgamated Leather Workers; W. C. Bowerman, of the London Society of Compositors; G. D. Kelley, of the Amalgamated Lithographic Printers; W. Coffey, of the London Consolidated Journeymen Bookbinders; W. Dyson, of the Amalgamated Papermakers; W. H. Wilkinson, of the Northern Counties Amalgamated Weavers; P. Walls, of the Blast

Furnacemen; J. Macdonald, of the London Trades Council; and W. C. Steadman, of the Trades Union Parliamentary Committee.

This list, it will be seen, embraces the most important industries of Great Britain, and it may further be remarked that the gentlemen who formed the commission were in a full sense representative of the various unions, for their visit was in every case authorised by their executive body, and in more than one instance was confirmed by a general ballot of the whole of their society.

The party left England about the beginning of November, 1902, and travelled in detachments distributed among the Cunard, White Star, Dominion, Anchor, Allan, American, and Beaver Steamship Lines. Immediately after their arrival the delegates started on a short tour of about a fortnight's duration. The purpose of this tour, which was kindly engineered throughout by the Civic Federation, was to give them a sort of bird's-eye view of the country, in order that they might gain some idea of its extent, of the vastness of its natural resources, and the stage of development which its industries had attained. Those who arrived at the more southerly ports of the United States, such as New York and Philadelphia, started from New York on November 12. Here again I had to thank the railroad companies, the New York Central & Hudson River and the Pennsylvania, over whose lines we travelled, for granting us the privilege of free transportation,—assistance which I valued not so much on its financial side as because I saw in it a sign of sympathetic interest in the objects I had in view.

The first place at which we stopped was Schenectady, New York, where we visited the works of the American Locomotive Company and the huge factories of the General Electric Company. We next proceeded to Niagara Falls, where we were joined by the remainder of the party, who had come by way of Canada, and who had already had an opportunity of seeing something of the industries of Buffalo. At Niagara we all inspected the great electric power plant, together with some of the industries that cluster round it, and the best part of a day was devoted to exploring the beauties of the Falls.

In the evening we boarded our Pullman car and went on to Cleveland. In that city we were most hospitably entertained, the capitalists, especially Senator Hanna, as well as the local labour leaders vying with one another in looking after our comfort and our instruction. One afternoon we spent in a steam-tug sailing round the harbour and inspecting the arrangements for the unloading of iron ore from steamer to railroad car, by which Cleveland handles over 25,000,000 tons a year with unsurpassed cheapness and expedition.

After this it was only natural that we should visit the shops of the Brown Hoisting Machinery Company, whose appliances play so important a part in this achievement. We also inspected the machine tool factory of Messrs. Warner & Swasey, where the mechanical fittings for the great Lick telescope were made, and some of the party looked over the shipbuilding yards, where they did not fail to remark that the Great Lake vessel is *sui generis*, and presents peculiarities of construction which could find no place in Great Britain.

The party next spent a couple of days in Chicago, where all inspected the stockyards and saw the ingenuity and organisation brought to bear upon the processes of packing pork. Visits were also paid to other establishments of various kinds, including the big department store of Marshall Field & Co., where the system of giving the employees money rewards for criticisms and suggestions concerning the management of the establishment provoked considerable comment.

From Chicago we went on to Dayton, Ohio, where the fine factory of the National Cash Register Company gave us a busy day. We were especially struck by the care and thought devoted to every detail of organisation, and also by the liberality of the treatment accorded the employees; indeed, the suspicion occurred to some of us that all that was done could not perhaps be altogether

justified on purely business principles; but, on the whole, the officials of the company were able to give a pretty good account of themselves on that score.

Our next stopping place was Pittsburgh, where the great attraction was the Carnegie Steel Works at Homestead, though various other works, such as those of the Westinghouse Electric & Manufacturing Company and of the Pressed Steel Car Company, also received attention. From Pittsburgh we went to Philadelphia, where Cramp's shipyard and the huge establishment of the Baldwin Locomotive Works were inspected. Passing next to Washington, the members of the party were each introduced to the President of the United States, who gave them a short address, and were received by the British Ambassador, Sir Michael Herbert. Mr. Carroll D. Wright, United States Commissioner of Labour, also delivered a short address, in which he insisted on the economic fallacy of restricting output, and maintained, in spite of denials from the British delegates, that such restriction had ever been the policy of British trades unionism, and that evidence he had collected showed clearly that it had been practised in Great Britain in some instances.

Finally we reached New York again on the evening before Thanksgiving Day, November 27, after an absence of just a fortnight. The members of the commission then separated again, each going off by himself to places where the conditions of the trade in which he was specially interested could be most advantageously studied. In this way another week or ten days was spent, after which the delegates began to return home, some, however, remaining for the annual convention of the Civic Federation, which was held in New York early in December.

When the invitations to take part in this tour were issued, it was understood that those who accepted should, on their return to Great Britain, write reports embodying the results of their observations and inquiries. To facilitate their labours in this task, and to secure as much uniformity and completeness in the answers as possible, experts were consulted and a series of questions drawn up which cover the ground pretty thoroughly. These questions give as good an idea of the scope and aims of the commission as can well be obtained, and, therefore, they are printed here *in extenso*:—

Early Training of the Workers

1.—Is the American lad better equipped by early training and education for his work than the British lad?

2.—If yes, what changes would you suggest in the British system of education for the working classes?

3.—Have you any suggestion to make with regard to evening continuation classes and technical education in evening classes for men at work during the day?

Relations Between Employers and Employed

4.—What are the hours of work in your trade in America and how do they compare with the hours in Great Britain?

5.—Does the American workman do more or less, on the average, than the British workman?

6.—Is the system of piece-work (piece-rates or time-piece-rates) largely used in America?

7.—Is this system of benefit (*a*) to the men, (*b*) to the employers? Does it give an unfair advantage to either side?

8.—When skilled workers on piecework increase the output per man by their own efficiency, do American employers cut down wages so as to prevent a man earning more than a certain amount?

9.—Are systems of premiums and bonuses commoner in America than in Great Britain, and, if so, how do they result for employer and employed?

10.—Where weekly wages are paid (*a*) Do the men show an anxiety to do their best and to give a fair day's work for a fair day's pay? (*b*) On this system do personal energy and initiative meet with a due reward?

11.—Are American employers anx-

ious to induce the workers on time-work to increase the output per man and to increase the wages per man in the same proportion?

12.—Are suggestions for improvements made by the employers and the introduction of labour-saving appliances and of up-to-date machines welcomed by the men, or the reverse?

13.—Are suggestions for improvements, made by the workmen, welcomed and rewarded by the employers?

14.—(*a*) Do the workmen attend on a larger number of machines than in Great Britain? (*b*) If yes, does the system benefit both employer and workman, or does either side reap an unfair advantage from it?

15.—Does the American workman require much overlooking? How does he compare in this respect with the British workman?

16.—Is the American workman capable of exercising initiative and of working without frequent and detailed directions? How does he compare with the British workman in this respect?

17.—Does the American workman exert himself at times of special pressure and at such times do overwork cheerfully? How does his overtime output compare with the output of the normal day; and how does he, in these respects, compare with the British workman?

18.—Are American employers more accessible to their men than British employers?

19.—Speaking generally, are there greater opportunities for the workingman to rise in America than in Great Britain?

20.—Are the needs of the workers in the matters of sanitation, ventilation, and general comfort in the factory better met in America than in Great Britain?

21.—(*a*) Do you consider American factories better equipped for production than British? (*b*) Are they better managed, and are a greater proportion of university-trained men employed in management than is the case in Great Britain? (*c*) Do the factories turn out better work?

22.—How far is greater output in American factories due to (*a*) longer hours of work; (*b*) greater speed at which the machinery is run?

23.—Are there any points in American practice which should, in your opinion, be imitated in British factories?

General Conditions of Workers Outside the Factory

24.—(*a*) Are the American workers better fed than the British? (*b*) How does the prices of food compare with that in Great Britain?

25.—(*a*) Are the American workers better clothed than the British? (*b*) How does the price of clothes in America compare with that in Great Britain?

26.—(*a*) Are American workers better housed than those in Great Britain? (*b*) How does rent in America compare with rent in Great Britain? (*c*) Do more workers, relatively, own the houses they live in than is the case in Great Britain? If yes, to what circumstances do you attribute this?

27.—How does the average wage in your trade in America, expressed in money, compare with the average wage in Great Britain?

28.—How does the value of the American wage compare with that of the British, cost of living being taken into account?

29.—Can the careful, sober, steady man, whilst keeping himself efficient, save more in America than in Great Britain?

30.—If yes, does he, in fact, save more, or not?

31.—Does gambling on horse-racing enter as largely into the life of the American as of the British workingman?

32.—Is the American workingman more sober?

33.—Is it true that the American workingman does a larger amount of work in early manhood, but that he deteriorates young, and that his working years are shortened?

34.—Is it true that the American workman is thrown out of work at an early age?

35.—(*a*) Is it true that the average life of the American workman is shorter than that of the British workman? (*b*)

If yes, is this due to overstrain, less healthy climate, or some other cause? (N. B.—It is suggested that the immense mass of statistics of the American insurance companies must throw some light on these important points, which should be investigated).

36. —Are a larger or smaller proportion of American workingmen dependent on the public purse than is the case in Great Britain?

37.—Do the children and friends of American workingmen who are past work, or incapacitated by ill-health or accident, help them to a greater extent than is the case in Great Britain? If yes, to what do you attribute the difference?

38.—Do you consider the general conditions of life of the workman better in America than in Great Britain? In what respects might American example be copied so as to improve the conditions of life in Great Britain?

General Questions

39.—Do you approve of the workings of the National Civic Federation in the United States?

40.—Could an organisation on the same, or somewhat modified lines, be introduced into Great Britain?

41.—Are the delegates in favour of taking steps to establish an organisation of this kind in Great Britain? (A full report on this point would be of value to fifty-eight workers in Great Britain).

Of the results of the trip of the commission it is as yet impossible to say very much. The more immediate ones will be. given in the reports which the members are to write in answer to the above questions. These will be published in due course, but until they are published nothing can be known, except in a very vague way, about their contents, because the delegates, naturally and properly, were reluctant to anticipate them with any detailed expressions of opinion.

My own views on the subject were indicated with sufficient clearness in the January number of CASSIER'S MAGAZINE, and need not be repeated here. As to the more permanent and valuable effects of this visit to America, they must of necessity come slowly. It is not to be expected that the habits and traditions of years are to be changed in a few weeks or months. But a visit to a foreign country,—especially to such a live country as the United States,—is bound, consciously or unconsciously, to broaden the outlook even of the most apathetic, and the members of the commission, so far from being apathetic, showed themselves, as a whole, ready and anxious to see and learn all they could in the time at their disposal. I hope, therefore, that their American experiences will prove to be the little lump of leaven which leaveneth the whole mass.

The delegates saw that the American worker receives much higher wages than the British, and that, on the whole, he is better fed, better clothed, better housed, better educated,—in short, that he lives on a higher plane generally, and I trust they will seriously consider how these things came to be, and whether something cannot be done in Great Britain in the way of approaching to conditions so desirable. I do not forget that the richness of America's mineral resources and the vast stores of food supplies freely poured forth by the boundless fertility of the Western plains are factors in her prosperity which Great Britain cannot hope to emulate; but, at the same time, there are other factors of which the imitation is not only perfectly possible, but would, I am convinced, increase the prosperity both of the British workman and of his country,—I mean, for instance, the use of machinery wherever possible, the whole-hearted welcome accorded to it by the workmen, the comparative absence of restriction of output, and the better relations which, generally speaking, subsist between employer and employed, to the mutual advantage of both.

With regard to the last-mentioned point I am encouraged to believe that the Commission will not be without benefit to British industry by the fact that the delegates, having learned something during their tour of the workings of the Civic Federation and its influence

for the promotion of industrial peace, after mature consideration drew up a declaration in favour of the establishment in Great Britain of a body having the same aims, but perhaps somewhat differently constituted. They were not, of course, able to pledge the different organisations they represent to definite approval of such a body; but they are to put the matter before their members, whose assent they hope to gain, together with the co-operation of other trade organisations throughout Great Britain. Even if the Commission were to result in nothing more than the establishment of a National Civic Federation in Great Britain I do not think that its journey to America would have been in vain.

Current Topics

AN interesting bit of investigation was carried out a short time ago at one of the electric power stations of Nürnberg, Germany, to find out how much power was being lost through fly-wheel air resistance. Two tandem-compound, 450 H. P. engines, direct connected to generators, and running at 95 revolutions per minute, are at work in the station, with fly-wheels having arms of channel section which were known to offer great resistance to the air, and on this account it was decided to encase the wheels with sheet iron and stop the evident waste. In order to find out what the loss of energy had been, one of the dynamos was made to serve as a motor for the unloaded engine. Without the fly-wheel covering there was thus found to be a motor consumption of 13,300 watts, while with the covering in place only about 9900 watts were consumed, showing a saving in this case of 3400 watts, or about 5¾ H. P. The money equivalent of this for a year was far in excess of the cost of covering the fly-wheels. In one other case of this kind, of earlier date, a saving of 30 H. P. was effected in a 630 H. P. engine by reducing this fly-wheel resistance.

THE most conspicuous example of the growing disposition to ignore boycotts and of the ineffectiveness of this form of intimidation in a community of average intelligence was supplied a short time ago in the American manufacturing town of Schenectady, the home of large electrical and locomotive building interests, where a street railway strike and boycott were declared, and failed because nobody paid any attention to them. Even the

wage-earners who were supposed to be parties to the boycott paid no attention to it. Men who live four or five miles from their work are not going to walk that distance. The business men paid no attention to it. Practically there was no boycott at all,—nothing but a threat which those who made it had no means of carrying out. A boycott is simply an attempt to intimidate a community, and if the community declines to be intimidated, the boycott is futile. Boycotters have no means of enforcing their decrees except by resorting to violence, and though this may go on for a little while, it never will last long. All of which prompts the *Manufacturer* to remark that without violence the only hope of the boycotters lies in intimidating the community. It is not altogether strange that the community is frightened, but it has been so often demonstrated that there is nothing to fear if people will not be afraid that it is about time boycotts ceased to be treated seriously. If merchants are warned that a large part of the community will not buy of them if they ride in a tram car, it is natural enough that most of them should practice pedestrianism for a day or so. If a workingman is warned that if he rides in a tram car it will be made impossible for him to get employment, he will naturally enough keep off the cars for a little while. But the population of a city, even a small one, is not going to sit down in idleness, and still less is it going to starve, and it is not going to put up with much inconvenfence about reaching its places of work and business, or getting its groceries, and presently it will be going about its usual business in its usual way.

A FEW years ago there was what promised to be a particularly formidable boycott of the tramways of a certain town. For a few days the place was intimidated. No one dared ride in a tram car lest his business should be boycotted, or lest his employer should discharge him for fear of being boycotted. But after two or three days of this sort of thing the people held a mass meeting and resolved that they would pay no attention to the boycott. Every man was willing to disregard it if he was assured that other people would do the same. The moment the citizens resolved to disregard the edict of a labour union, the boycott collapsed. Everybody rode in the cars and everybody bought his groceries and his shoes and his coal where he had been accustomed to trade, and there was no interruption of the city's business. Of course there were some attempts at violence, but even the politicians could see that the people who were to be boycotted were in a great majority, the boycotters being but a small minority of the population, and the police suppressed the rioters. Several other towns have had similar experiences, and as soon as the population got over being scared they found there was nothing to be scared at; the boycotters could not do anything to them.

REFERRING to the statement in these pages for December, 1902, concerning electrolysis of underground gas and water pipes from stray electric currents, that "one ampère of electric current flowing steadily from an iron pipe in a suitable electrolyte will corrode one pound of that metal in one year," Mr. L. Clifford Anderson calls attention to the fact that with the ruling electrochemical equivalents of iron the weight in pounds of metal liberated per ampère-hour are 0.001535 when a ferric salt is formed, and 0.002303 when a ferrous salt is formed. Assuming an electric railway to be operated for twenty hours each day, which is average practice, there would be 7300 working hours yearly, and one ampère flowing constantly during this time would make 7300 ampère-hours. Multiplying by the constants just mentioned would give 11.2 pounds and 16.8 pounds, respectively, as the amounts of iron removed from a pipe when ferric and ferrous salts are formed, instead of one pound, as erroneously stated in that earlier paragraph. As to the suggestion that dam-

age to pipes from electrolysis might be averted by insulating the pipe joints at intervals, Mr. Anderson aptly remarks that essentially the same thing is done now in all cast iron piping systems, for at every bell and spigot joint the two films of tar coating and the oxide on the surface of the metals form a path of high resistance, varying from a few times to thousands of times the resistance of an equal length of cast iron pipe. The effect of this high resistance at the pipe joint is to shunt part of the current around the joint, either through the surrounding soil, the water in the pipe, or through both, resulting in electrolytic action at the positive side of the joint. While increasing the resistance of the pipe lines by the method proposed, granting it can be applied, would decrease to some extent the amount of current flowing on the pipes, it would very materially increase the damage at every point on the system where the high resistance joint is inserted, since practically all of the current would be shunted around the joint.

THE idea of a "safety" dress for the protection of those whose business requires them to work around high-pressure electrical apparatus appears to be an inviting field for inventors. The idea is not altogether a new one, however, for over ten years ago, when the fatalities due to contact with high-tension overhead wires were numerous, a number of protective devices to be worn on the body were exploited; but so far as known not any of them have been adopted. Somewhat recently Prof. Artmeiff has devised a safety dress of this nature which is said to be quite efficient. The dress, which has been tested in the high-tension laboratory of Siemens & Halske, consists of fine, thickly woven wire gauze which covers the feet, head, and hands of the wearer. Its weight is 3.3 pounds and its resistance is 0.017 ohm from hand to hand, practically inappreciable as compared with the resistance of the body. Wearing this dress, the experimenter freely subjected himself to a number of rather hazardous tests, amongst others, one in which, with safety to himself, he short-circuited with his mailed hands the terminals of a generator that was developing 1000 volts and 200 ampères. A rule requiring the use of such a dress, however, would probably be found quite as difficult to enforce as the rule which requires the employees of the different electrical companies to wear rubber gloves,—a rule which, notwithstanding that it is obviously in the interest of the employee, is perhaps as often illustrated in the breach as in the observance.

SOLIDIFYING petroleum is not a new art. It was practiced many years ago with the object, of course, of using the new product as fuel, but generally the oil in its new shape was of such a character that its combustion was attended with objectionable features, making its use impracticable; or it was so expensive as to make the cost prohibitory. Now, however, a new process of solidifying crude oil has been brought out by a Chicago company, the Standard Petroleum Briquette Company, with which all these drawbacks are claimed to be avoided. A large plant for turning out the new briquettes,—a thousand tons of them a day,—is, according to report, to be built at Port Arthur, in Texas, as a forerunner of several others in some of the newer American oil districts, and the briquettes are to be supplied at tidewater at a cost of production of about $1.20 a ton. Their heat value, when made from Beaumont, Texas, oil, is said to be about 18,000 B. T. U. per pound,—slightly less than that of the oil originally, owing to the elimination of the sulphur and the escape of some of the gaseous constituents during the process of solidifying. Trials made with some of the briquettes are said to have shown that they burn with a strong, hot flame, from the upper surface downward, leaving practically no residuum. Other constituents, such as coal dust, sawdust, refuse from oil refineries and numerous other substances,

may enter into the composition of the briquettes in any desired proportion, one result of which, however, is a reduction of heat value for the substance. For a great many purposes this is desirable because of the intense heat from the purely petroleum bricks. Advantages are claimed for the fuel over both coal and liquid petroleum. To burn the latter, boilers must be especially equipped with suitable apparatus; also special facilities for transporting and storing the oil must be provided. There are objections to storing oil in large quantities, chief of which is the danger in case of fire; under many circumstances such storage is not permissible at all. The solidified petroleum, it is claimed, will not ignite unless a flame comes in contact with it; it is claimed, also, that there is no danger from spontaneous combustion.

In comparison with coal, one important consideration is the higher calorific power of the oil fuel. This is of especial importance for ships, where it would mean increased mileage on a given bunker capacity, the briquettes occupying practically the same space as coal, weight for weight. Another point is the ability of the new fuel to raise steam quickly. The preferable method of burning the fuel is to use a chain grate, the briquettes being fed in uniformly at the front. Air should be admitted over the fire,—none whatever coming through the grates. It may be burned in locomotives with but few changes, finer grates being necessary to support the fused mass and provision should be made for admitting the air at the front of the fire-box.

One point to which prominence has been given in discussing the merits of the steam turbine is that this type of engine may be used unreservedly with superheated steam of any feasible temperature. As remarked by Mr. E. H. Sniffin in a recent paper dealing with the commercial aspect of the steam turbine, it has no internal rubbing surfaces, and there are no glands to become injured. Also, as no cylinder oil is required, there is no opportunity for lubricating trouble. Furthermore there seems to be with the turbine rather more proportionate benefit from superheat than with the piston engine, because of diminished skin friction. Having said that the turbine requires no cylinder lubrication, the inference follows that the steam is therefore uncontaminated with oil, and that the exhaust, when condensed, is pure distilled water. This is true, and while it is of little consequence where water supply is abundant and good and cheap, it becomes of exceeding importance where conditions are otherwise. In many places where the water contains either mud or scale-making impurities the cost of repairs to boilers, with the expense in labour and interruption of service entailed by constant cleaning, is a besetting evil, and to alleviate this trouble large surplus boiler plants are often installed. As a usual thing, too, difficulty is experienced in attempting to extract oil from exhaust steam. To recur once more to this feature of lubrication in the turbine, it may be remarked that it is an item of very little expense. The bearings are the only points requiring oil, the lubricant being circulated around under pressure. The reservoir being once charged, very little is needed to maintain the supply.

By the most conservative class of mechanical engineers the steam turbine is still regarded as in an experimental stage; but, as a rule, it is being received with favour, and, while it is acknowledged that tests have shown a high degree of economy, fully up to if not beyond the standard of the compound condensing engine, it is pointed out that few installations have been in operation a sufficient length of time to demonstrate the difficulties which may be encountered through extended service. Figures presented at a recent meeting of the British Association for the Advancement of Science, however, indicate that the

turbine is being generously adopted for electric driving and as a marine engine. Its first use as a turbo-generator was in 1884, and by 1890 altogether 360 plants, ranging from 4 to 120 horse-power and aggregating more than 5000 horse-power, had been installed. From the same source it is learned that there are now in use, and building, turbines aggregating over 300,000 horse-power, the largest turbine installed being of 3000 horse-power. The difficulties in designing large turbines seem to have been overcome, and turbines up to 5000 horse-power are now under construction.

"FOG BOXES" for high-voltage electric line insulators will probably strike most readers as new things in the list of electric appliances. They appear to have originated with Mr. J. J. Davis, superintendent of the United Electric, Gas and Power Company, which operates a number of plants on the Pacific Coast of the United States, one of them at Santa Monica, about twenty miles from Los Angeles, California, directly on the sea beach, supplying a number of small towns with electric light and power over a 22,000-volt line. This, for several miles of its distance, is either directly on the coast or but a short distance back from it. Ever since the installation of this high-tension line, the company has experienced the greatest difficulty from current leaking over the surface of the insulators and burning off the pins. This was caused by fogs, which are very thick along the coast. It was found that the line worked perfectly in wet weather, but in dry weather dust would accumulate under the bell of the insulator, and in time of fog, the moist atmosphere would pass under the insulators, depositing moisture on the dust, which would form a sort of paste and establish a sufficiently low-resistance path so that the high-voltage current would flash across. In a short time the pins would burn off, with the natural result that the wire dropping on the cross-arm would burn the cross-arm off, and ultimately swing against the pole, burning it off. Mr. Davis states that the company tried many schemes to overcome this difficulty before he hit upon the novel device of fencing in the pins and glass. This new arrangement, he reports, has been shown by practical test to have completely overcome the leakage, and to prevent the burning-off of the pins.

THE fog-box, as the new device has been named, and of which the annexed illustration has been reproduced from the *Electrical World and Engineer*, is made of one-inch redwood, 12 inches square, and 4¼ inches deep. The box has in its top a round hole 10 inches in diameter, which leaves about 1½ inches all around the outer edge of the insulators. The boxes come up within two inches of the wire, and are mounted on the cross-arm. Previous to the adoption of this scheme, there was one section of five miles of line paralleling the beach which had to be patrolled day and night. The boxes have now been in use, on part of the line, about one year. The leakage from the insulators was clearly not the fault of the insulators because the types used have been successfully used with higher voltages in other places, and in wet weather there was no trouble on this line. The trouble came with the fog after a period of dry weather. The company has experimented with insulators made for 80,000 volts working pressure, and the same trouble was experienced as with other insulators. Apparently, the boxes keep

A FOG BOX ON A HIGH-TENSION LINE

the dust and fog from drifting in under the bells of the insulators. Mr. Davis does not consider that a transmission line at very high voltage will ever be successfully operated along a sea coast where there are fogs. To illustrate how trying the conditions are, Mr. Davis cites one case where the company had a 2300-volt line on glass insulators made for 30,000 volts working pressure, and in a heavy sea-fog, when the insulators would get a trifle dusty, the 2300-volt current would leak over and burn the pins. When this happens with only 2300 volts, it can easily be imagined what difficulty the company would have in operating without fog boxes on its 22,000-volt line.

ACCORDING to Mr. Thomas H. Leggett, the well-known South African mining engineer, the notorious inefficiency of white labour on the Witwatersrand is not due to the living conditions but to the use of kaffir labour. Every mechanic wants, and generally gets, a "boy" to carry his tools for him; and, underground, most of the hard work is done by natives, who are even learning to run air-drills while the white men do the "bossing." This is a condition always met with where white and black labour come in contact. It is, in fact, a governing condition in South Africa, to last as long as kaffir labour is used, *i.e.*, practically always.

IN discussing the relations of the manufacturing industries to national progress, Dr. Robert H. Thurston recently remarked that a generation ago it was difficult to secure from the employer the slightest consideration for the educated professional, while the so-called "practical man" was attempting to lead, as general, the industrial armies of the nations. To-day the industries are being rapidly transferred to the direction of the technically educated leader, the product of the work of the science-teacher and the engineering school. With a thousand passing out into business each year, the demand still exceeds the supply, and the leading schools and colleges of engineering are compelled to reply to the applications of the manufacturer, or other proposing employer, "Not a man unengaged." Educated men, once abused as conceited, helpless, and useless, are now found to be precisely the men for the work, and the now efficient training in shops and laboratories, supplementing their general education and scientific acquirements, is discovered to be exactly adapted to their advance from the ranks to the position of commanding officer in any department. Another generation will see industrial systems everywhere practically under the hands and direction of these technically trained men.

SUBSTITUTES for coal have for many years commanded attention, and especially so during the past eight or nine months in the United States, with coal prices at abnormal figures as a result of the anthracite miners' strike last year. Peat and briquetted sawdust, wood, oil and many other substances, have been under consideration, and among them also corn, this last particularly having been spoken of as something quite new, though, as a matter of fact, corn has, for a long time, been used as fuel in the farming districts of the western sections of the United States, and that, too, with very satisfactory results. In a general way, it was recognised there that when corn was abundant and cheap, and coal was expensive, the former made a cheaper fuel than the latter, although no scientific determination of their relative efficiency had been made until a few years ago, when tests were made by the Department of Agriculture of the University of Nebraska. An account of these, given in these pages at the time, showed, among other things, that an acre of land will produce from 40 to 80 bushels of corn, which, if burned, will yield from 22,512,000 B. T. U. to 45,024,000 B. T. U., not counting the heat that could be obtained from the

stalk. Since a ton of good coal will give up from about 20,000,000 to 26,000,000 B. T. U., an acre of ground is each year capable of producing fuel which is equal to from 0.87 or 1.28 to 1.74 or 2.56 tons of coal. The stalk will probably increase this amount by one-fourth or one-third.

THE experience gained from boiler tests with corn fuel made it appear doubtful whether corn would be a practicable fuel for the generation of power, unless it were burned in some special furnace that would insure the perfect combustion of the volatile matter which forms so large a percentage of the whole corn, and which is driven off at a comparatively low heat. Some form of automatic stoker would also be desirable, since the corn burns rapidly and must be frequently fired, making the work of the firemen very arduous, and at the same time tending to cause incomplete combustion by the excess of cold air entering through the fire door. Undoubtedly corn may, at times, be a cheap and economical fuel for domestic use. It is cleaner and more easily handled than coal, and contains but a very small amount of ash. It burns rapidly with an intense heat, and this is apt to be destrucive to the cast iron linings of the stove. Here, again, therefore, some special form of fire-box, that will not be injured by the heat, and that will utilise as much of the heat as possible, should be used.

CLEMENT ACTON GRISCOM

PRESIDENT OF THE INTERNATIONAL MERCANTILE MARINE COMPANY

AS president of the International Mercantile Marine Company, Clement Acton Griscom has come, more than ever before, into the public eye, not only in his native country, the United States, but in Great Britain and on the European Continent as well, where the workings of the shipping combination have been followed with close attention.

Born in Philadelphia in 1841, the descendant of a family which has been identified with the history of that city since the seventeenth century, he inherited traits of character which enabled him to take rank among the prominent men of the day. His first occupation proved congenial and determined his future career. Entering the employ of the importing firm of Peter Wright & Sons in 1857, he at once gave evidence of those traits which, at the early age of twenty-two, gained for him partnership in the business. Under his directing influence the firm began to purchase sailing ships for their trade and the profits increased immediately and largely. More vessels were purchased, the business grew to larger and larger dimensions, and eventually Peter Wright & Sons became the agents of the old American Line, one of the prominent steamship lines of that time.

After this came the formation of the Red Star Line, accomplished through Mr. Griscom's negotiations directly with King Leopold of Belgium, and the combination of this and of the old American Line gave rise to the International Navigation Company, with Mr. Griscom thus one of the founders of a great power in the transatlantic trade. He became vice-president, and, later, president of the company, controlling and operating twenty-six steamships, one of the largest fleets in the trade.

The old Inman Line was purchased by the company in 1886, and subsequently it contracted for the steamships *New York* and *Paris*. Through Mr.

Griscom's energy special Congressional legislation was secured which permitted these ships to sail under American registry. An important event was the placing of the contracts for the ocean liners *St. Louis* and *St. Paul*, which were awarded to the William Cramp & Sons Ship & Engine Building Company, and the result proved that his confidence in the ability of American shipbuilders was not misplaced. In the Spanish war the United States government secured the use of several of the company's ships, including the *St. Louis*, the *St. Paul*, the *New York*, which was temporarily known as the *Harvard*, and the *Philadelphia*, which during her term of Government service was called the *Yale*. These played an important part in the naval engagements, thus attaching to the boats a historic interest.

In September, 1902, the shareholders of the International Navigation Company in the United States increased the capital stock of the company to one hundred and twenty million dollars (£24,000,000), in order to provide the means for the acquisition by the International Navigation Company, Limited, of Liverpool, its counterpart in Great Britain, of the shares of several important steamship companies, the gross tonnage of which, including the tonnage already owned by the International Navigation Company, was 1,103,739 tons.

Thus was brought into existence the International Mercantile Marine Company, to take the place of the International Navigation Company. It includes the White Star, American, Red Star, Leyland, Atlantic Transport, and Dominion lines, and has a working agreement with the Hamburg-American and North German Lloyd steamship companies, and of this vast aggregation of shipping interests Mr. Griscom is the leading spirit.

Notwithstanding the vast responsibilities connected with the steamship enterprises of which he is the head, Mr. Griscom is active in many other lines. Having taken up the study of marine architecture several years ago, he became the first president of the American Society of Naval Architects and Marine Engineers when this body was formed, and to this office he has been re-elected each successive year. He is a director of the Pennsylvania Railroad, the Bank of North America, the United States Steel Corporation, the Atlantic Mutual Insurance Company, the Fidelity Trust Company, and many other financial institutions. He was also one of the organisers of the National Transit Company and served as its president for several years.

In 1889 Mr. Griscom was one of the American delegates to the Interational Marine Conference for revising the "Rules of the Road at Sea," twenty-eight nations being represented. He was also made an honourary member of the Institution of Naval Architects of Great Britain, an honour conferred on but three others at that time, the Grand Duke Constantine, of Russia; Lord Kelvin, and Depuy DeLome, of Paris.

The Queen of Holland conferred the decoration of Knight of the Order of Orange-Nassau upon Mr. Griscom, in recognition of the perfect discipline established upon the steamships of the International Navigation Company. The particular occasion which instigated Her Majesty to confer that decoration was the rescue, by the crew of the American Line steamship *St. Louis*, of the passengers and crew, consisting of two hundred and twelve men, women, and children, from a disabled Dutch transatlantic steamship, which sank shortly after the last boatload had left the wreck. Mr. Griscom was also one of the prominent citizens of the United States selected recently by the French government to receive the decoration of Chevalier of the Legion of Honour.

With so many and such varied responsibilities one would naturally think that Mr. Griscom had little time left for home life, and yet he is essentially a family man. While he has a town house at Philadelphia, he lives most of the time at his country home, "Dolobran," in Haverford, near Philadelphia, and here is never so happy as when his house is filled with guests. He is a good companion, and popular with his fellow men.

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CASSIER'S MAGAZINE

VOL. XXIII MARCH, 1903 No 5

GREAT BRITAIN'S NAVAL SUPREMACY

By Archibald S. Hurd, author of "Naval Efficiency: The War Readiness of the Fleet"

MUCH is heard of the ship-building programmes of the various Powers, of the designs of the ships which it is proposed to lay down, of new inventions which will make warfare more deadly, of shortness of officers and men, and of other details of preparedness or unpreparedness; but little is known of the actual progress which is being made in strengthening the fleets which are at sea, ready for any emergency. It is by such readiness that the strength of a country afloat can be measured rather than by a mere "counting of noses."

The next campaign will depend less on the number of ships,—many of them skeletons, ill-found and under-manned, it may be,—than upon the well-trained crews, the engineer and his staff below, the torpedo officer, and the gunnery officer and his marksmen at the great weapons, and, above all, on the nerve, courage, coolness, and resourcefulness of the admiral in command and of his captains. These qualities in officers and in men can be cultivated only in sea-going squadrons, moving from point to point in all weathers, frequently practising evolutions, and week after week endeavouring to improve the fighting efficiency of each ship. The strength and equipment of a nation's squadrons are the real facts by which it should be judged.

On paper the British fleet is the strongest in the world. What is the character of the British squadrons? Great Britain is a Power supported by old traditions, and, therefore, slow to reform, and one, moreover, which has been inclined at times to assume that what was accomplished at Trafalgar could be done again with ease if the occasion arose. In fact, prestige has been regarded in the British Navy as a fighting asset, and officers ten years ago were satisfied that, whatever happened, the British fleet would secure victory.

In recent years an awakening has taken place at the Admiralty and in the squadrons. Many influences have warred against reform, but they have availed only to delay progress temporarily. The movement, supported by popular opinion, has been irresistible. Never was there a time when more attention was devoted to the organisation of the country's marine resources, and never was more care exercised in training the crews of the men-of-war in the stern duties which will devolve upon

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ONE OF THE SUBMARINES

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them in time of hostilities. In fact, with the appointment of Rear-Admiral W. H. Fawkes in place of a commodore to command the new Cruiser Squadron and the strengthening of that force by the substitution of two of the newest and largest armoured cruisers for two protected ships, the British Admiralty have completed the reorganisation of the naval forces in the "Narrow Seas."

Little has been heard of this work, because it is not the way of the authorities at Whitehall to proclaim their intentions from the house-tops. Now that the task is, for the present, completed, and stands confessed in the eyes of the world, it may be interesting to glance back five years and see what has been accomplished and consider the influences which have led to recent changes in the disposition of the British squadrons on which, in time of war, the brunt of an enemy's attack would fall.

All the circumstances affecting the policy of British naval defence have undergone radical changes of late years. Prior to 1897, or even as late as 1900, Great Britain had to take serious ac-

count of only two rivals in sea power,—France and Russia. These two competitors remain, but they are no longer alone on the seas threatening Britain's supremacy. In Europe Germany has entered the arena, and among the extra European navies the United States is asserting her position as an all-world Power, while Japan has joined the councils of the great nations. Each of these countries has adequate naval forces at its command to ensure respect for its flag wherever it may be flown, and the future of each is big with possibilities.

At the same time, Italy, which Great Britain was accustomed to regard as a standby in the maintenance of her position in the Mediterranean, has permitted the strength of her navy to decline relatively to the efforts of other Powers, while British relations with Rome have also undergone a partial change. In the Western world the British Navy stands alone, an isolation unparalleled in the latter half of the nineteenth century; but in the Far East, the scene of Russian naval and diplomatic activity, she has by her side the splendid army and navy of Japan in face of a common danger. Britain is relatively stronger east of Suez, but in Europe her position has been seriously weakened; the British fleet is isolated, surrounded by inimical forces twice as numerous as they were ten or even five years ago.

These alterations in the diplomatic position in Europe have been reflected in the arrangements made by the British Admiralty for the effective defence of the Empire. Looking back over the past few years, in some cases months only, it is interesting to witness the deliberate purpose and the reasoned foresight which have dictated the policy of the naval authorities. It is an axiom that the dispositions of ships in time of peace must be such as will best suit the strategical problems which will be unfolded on the outbreak of war; and "war is a business of positions."

It is a mere frittering-away of the resources of a nation to dissipate its resources without any set plan merely to show the flag in various parts of the world. This is a danger to which the greatest Powers are open because traders, possibly rightly, attach much importance to this process of showing the flag. But this exhibition in far-off ports, legitimately helpful as it may be to the

ANOTHER VIEW,—ON A TRIAL SPIN

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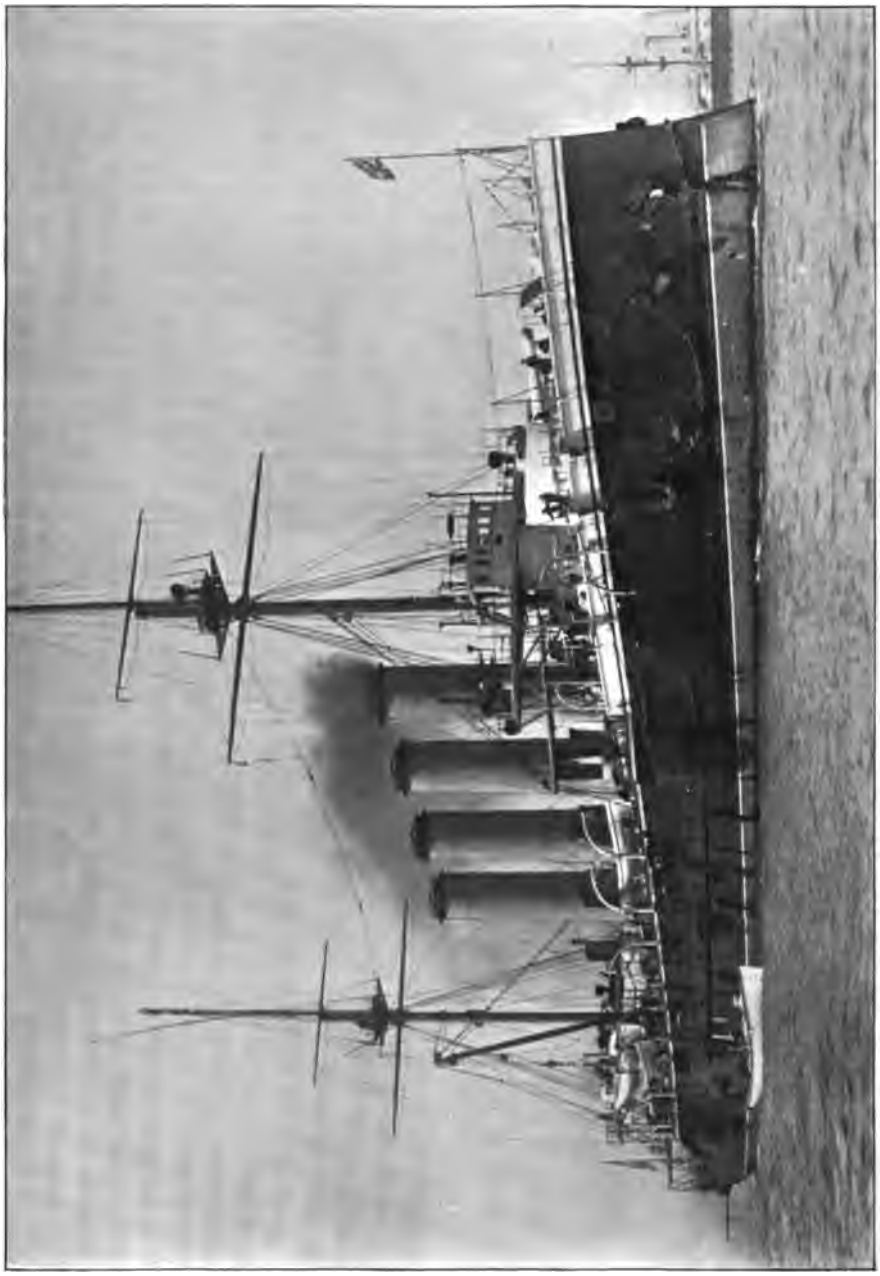

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pursuit of commercial aims, is dangerous in the extreme if it weakens the capacity for warlike action.

There are two classes of navies,—those which are maintained for purposes of defence pure and simple, such as those of Holland, Denmark, Austria, Spain, Greece, and others, and those which keep the seas and are intended to fight wherever an enemy may appear, such, for instance, as those of Great Britain, France, Russia, Germany, the United States, Japan, and, to some extent, Italy. The countries in the latter category, and especially Great Britain with a huge colonial empire, as distinct from her neighbours' colonial possessions,—an important distinction,—and her surpassing over-sea commerce, are open to the temptation to distribute their strength over wide areas for the mere pride of show or to encompass some special purpose. For instance, Russia has greatly weakened her strategical naval position in the west by taking a large proportion of her ships from the Baltic and placing them in the Far East. Great Britain has been face to face with seductions of a like kind without so substantial an excuse; but in reviewing the naval situation it is noticeable that a wise restraint in the past has left the authorities at Whitehall free to meet the more pressing needs nearer home, at the very heart of the Empire.

Diplomacy has required, as it must always require, that it shall be adequately supported by the right arm of the British Empire, which is, and must ever be, the fleet, and consequently additions have been made to the British squadron in the Far East. A few years ago Britain was supreme in the Pacific waters that wash the coasts of China; yet there was not a single battleship in that region. Four fairly large cruisers,—the largest of 8400 tons displacement,—and fourteen small ships, suitable for the navigation of shallow rivers, carried the white ensign. As late as 1897 there was only one British battleship in Chinese waters. Gradually the squadron has been transformed from a squadron of observation and for the protection of local trade interests into a fighting unit of high value. Battleships have been added, and to-day the squadron includes no less than five armoured ships, four of them sister battleships of 12,950 tons, the *Albion*, *Glory*, *Goliath*, and *Ocean*, and the fifth, the new armoured cruiser *Cressy*, of 12,000 tons.

Supporting this battle fleet,—for the *Cressy* is a light battleship in all but name,—are four first-class and four second-class protected cruisers and twenty-five smaller cruisers, gunboats, and other craft, including six torpedo-boat destroyers, the whole force in commission all the year round. A few years ago this squadron had only one admiral to control it. To-day its growth has necessitated the appointment of a junior flag officer, while a commodore is in charge of the naval establishments at Hong Kong. During the height of the troubles in China the temptation to add an even larger number of ships to this distant force must have been great; but as it could be done only at the further expense of the Mediterranean squadron, it was resisted.

At that time the paralysis following upon the engineering strike held many skeleton ships at home, and the augmentation of the China squadron could have been effected solely by borrowing additional vessels from the "Narrow Seas" and jeopardising interests which must be the supreme consideration of the British government. A wise discretion, coupled with causes of disorganisation then apparently beyond their control, prevented the Admiralty from weakening the essential links in the chain of imperial defence in order to strengthen those at its end.

The conclusion of the defensive alliance with Japan indicates what was merely suspected at the time of the turmoil in the Far East. The British government was aware then that although the moment was inopportune for the drawing up of a formal treaty which might have brought affairs to a climax desirable to avoid, the friendship of Japan was there in the last resort, and the fleet of this rising Power in the Far East would be found co-operating with Great Britain in defence of the common

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policy of the two countries,—the maintenance of the integrity of China and the "open door." Last year occasion was seized to crystallise this understanding and to warn the world of its existence. Consequently, it is apparent that the present strength of the China squadron in alliance with the whole navy of Japan gives to the signatories to the treaty a power which is unrivalled in those waters.

A study of the constitution of the other British squadrons in foreign waters, as they exist to-day and as they were in 1897, reveals a similar recognition of the truth of the old adage that the strength of a chain is the strength of its weakest link. There are sure to be weak links, and the British Admiralty, with due regard to the strategical necessities of the Empire, have determined that they must not exist at vital points. In face of an all-world competition for sea power the authorities have kept their head. Foreign squadrons seemed, on consideration of their individual needs, to require strengthening. Probably if the truth were known, every admiral in command of a British squadron in the past five or ten years of shifting trouble has expressed himself dissatisfied with the force at his command. It is human nature, and even British flag officers are human.

Every mother thinks her children the finest, and every admiral probably considers the portion of the world's seas given into his charge of more vital importance to the Empire than the central authority does. It is the duty of the Sea Lords of the Admiralty, with their unrivalled information of the trend of diplomacy and their appreciation of the strategical necessities of the Empire as a whole—they are in a position to have both—to settle all such questions.

The result of their past deliberations may be seen.

Some of the distant squadrons have been somewhat strengthened, but only as the greater needs of the vital portions of the chain of imperial defence permitted, and two,—the Pacific and south-east coast of America,—have been deliberately reduced. The needs of the Australian colonies have called for special protection, but the augmentation of this squadron has been due to local causes. It may be that in consequence of the adoption of steam propulsion and the high speeds which tend to annihilate distance, further changes in the direction of the increased concentration of the naval forces of the Empire may become essential. The longer the chain, the greater must be the risk of a rupture. The day may be near, in view of the growth of European armaments, when Great Britain may be forced to draw in her strength and mass it nearer home in time of peace so as to be the more ready for an emergency.

A policy of concentration has marked British naval expansion of the past few years, though, owing to causes which need not be enumerated, it has been less emphasised at the Cape. Concentration, not dissipation, has been the aim of the Admiralty. The colonies are growing in wealth and importance, but it is still their interest and that of the people of the British Isles to jealously guard the means of communication.

The twenty-five States of Germany are knit together by railways, commercial and strategic, and by an increasing network of canals. These means of transit are all at the service of the imperial authorities for military purposes, and, in time of peace, are organised with this end in view. Germany has land frontiers which may be attacked, and she devotes thought and money to the development of the channels by which she can move her army corps with the greatest celerity to the points of danger.

Russia is spending colossal sums in similarly welding together by steel rails

ONE OF THE SIX-INCH GUNS ON THE "DIADEM"

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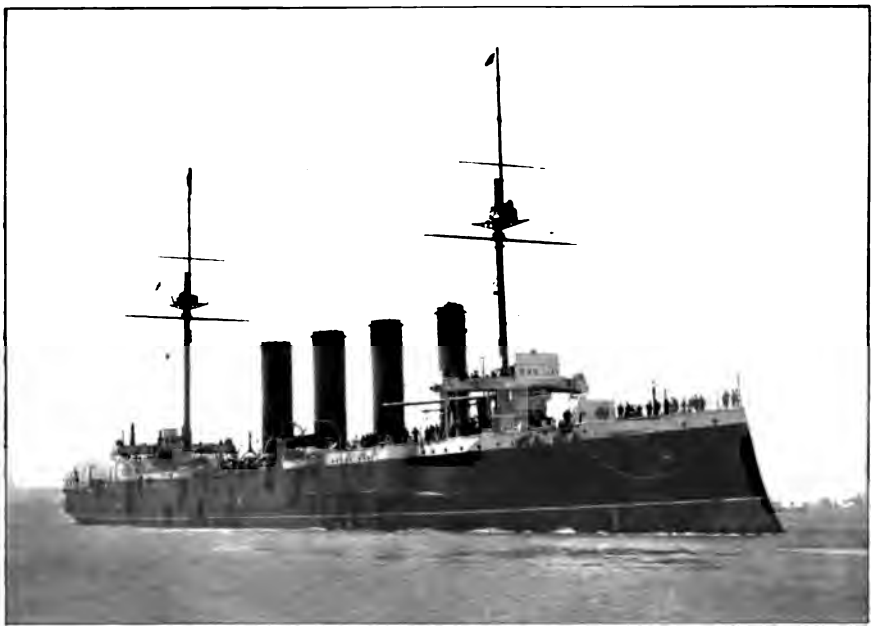

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the immense empire over which the Tsar rules. In fact, Continental powers have in the past twenty years seen the urgent necessity of perfecting the means of communication between various parts of their empires.

What the railways are to the great powers of Europe the seas are to Great Britain and her colonies. As there are some railways and canals in Germany more vital than others, so to Great Britain there are some seas which must be held more securely than others.

Command of the sea is a phrase which is frequently used with all the looseness that comes of familiarity. In the present state of the world and its friendships and enmities it is apparent that it is a less formidable business than is sometimes imagined. Great Britain has Japan as an ally, and, it is hoped by Englishmen, the United States as a friend, for there is something still in the proverb that blood is thicker than water, in spite of the occasional clamour of some of the elements among the people of the United States. The British people, therefore, lay store by the friendship of Japan in the Far East and of America in the Far West.

The sources of possible danger to Great Britain are the two great Alliances, the Dual and the Triple. The Admiralty have been so accustomed to lay their plans for the former that public opinion is still unprepared to believe that Britain can have any cause to be specially on its guard against the Triple Allies. Is it not, however, significant that at a time when the German people are building a navy which will seriously threaten British supremacy, those ancient ties of friendship between Great Britain and Italy should have been weakened? However that may be,—and it will be shown that the fact has apparently not escaped the notice of the Lords of the Admiralty, whose province it is to study the problems of strategy as they present themselves,—it is the "Narrow Seas" that Great Britain must command, at all costs, since it is these which are the highways of rivals.

The whole structure of the British Empire, the flow to the British Isles of the raw material for industries, the very bread of the inhabitants depends not on the forces which can be massed in the Far East or in the Pacific, but on the strength of the squadrons that fly the Union Jack and the White Ensign in the "Narrow Seas," in the Mediterranean, in the Channel, and, in an increasing degree, in, or adjacent to, the North Sea. These waters are the junctions of the all-world powers of Europe, and so long as Great Britain is secure at these points any temporary check elsewhere can be righted. Nothing can retrieve the position in the "Narrow Seas" once it is lost. For the triple, as for the Dual Alliance, it is the gateway of empire and of commerce. These waters are, above all, the pathway to the great Indian Empire and to the Australian colonies, and it is on them that the Empire will be lost or consolidated in blood when the clash of war comes. The essential links in the far-flung chain of defence must be in these waters, to be stretched out or contracted as the changing situation may demand and the national purse can afford.

When Lord Roberts advanced through Bloemfontein to Pretoria, and, one after the other, occupied the chief towns of the two conquered South African Republics, the pressing problem was to keep open the long line of communication with Capetown and the branch lines for the supplies to the centres on either side of it. It was urgently necessary that Capetown should be secure and that the great trunk line should be unbroken. Interruption in the branch communications might occasion temporary inconvenience and even suffering; but any serious stoppage of supplies along the trunk line would spell disaster. What the Cape to Pretoria line of communication was to the Commander-in-Chief, the ocean track from the ports of the British Isles, past Gibraltar, Malta, Cyprus, Alexandria, and Aden is to the British Empire. This is the Empire's trunk line, on which its existence depends. While Britain holds this in overwhelming force, no possible enemy can permanently injure by war the Empire or its commercial life. It is the

main artery of the British body politic. Germany, France, Russia (at present), Italy, Austria are shut in and impotent so long as this trunk line is guarded in sufficient force by the British fleet.

Can this task be accomplished? This is the problem with which the British Admiralty have had to grapple, and a review of the changes which have been effected in the disposition of the forces at their command reveals the fact that they have not been unmindful of the growing naval power of the German Empire, of the increased French concentration in the midland sea, or of the changed relations with Italy. Spectators of the great assembly at Spithead, where the squadrons attached for supplies and stores to the home ports gathered to signalise the coronation of the King, must have been impressed with the changes which have occurred since the former great review at this anchorage in 1897.

No more impressive spectacle was presented than was witnessed when the British Home Squadron, comprising the coast and port guardships, joined the array. In long lines the Channel and Cruiser Squadrons and other home-service vessels were drawn up,—seventy-five fighting ships, large and small,—stretching from No Man's Fort far beyond Stokes Bay towards the entrance to Southampton Water. Then there swung past the eastern end of the Isle of Wight the ten battleships and accompanying cruisers of the Home Squadron.

In 1897 it was a loosely-composed, heterogeneous collection of ships which spent eleven out of every twelve months swinging round moorings in the harbours on the coast. What a change Admiral Sir Gerald Noel,—the officer whose decisive diplomacy settled the Cretan difficulty, it will be remembered,—had effected! He brought to Spithead not, as before, a ragged mob of ships, but a well-manœuvred, self-respecting squadron, accustomed to manœuvring in company several months in the year and fully manned. In stately fashion this newest sea-going fighting squadron of the Empire passed down the line of Channel ships on their southern side, and then, wheeling round, came up in one long column on the other side in perfect formation, and at a signal from the flagship the whole squadron, as one ship, plunged its anchors into the water and stood still on the face of the waters, each vessel in the exact position assigned to it. The scene was an eloquent reminder of the transformation which has been effected in this naval force since the celebration of the Diamond Jubilee, and the spectacle of the six modern cruisers in an adjoining line,—the Cruiser Squadron,—revived memories of the four picturesque, but useless, training ships which they have replaced since 1897. Nor were these the only two reminders of the progress which has been made in late years, for nearer the Hampshire coast lay the twenty-eight torpedo-boat destroyers, which are now always in commission at the home ports and most of the year actually at sea. Since the review a further change has been made, and most of the Home Squadron ships are now at sea, not occasionally, but always, constituting what is styled "the Home Fleet," an additional force for duty in the "Near Seas," while the battleship *Audacious* is on duty off Felixstowe as the "mother ship" of the Chatham destroyer flotilla which is continually cruising in the North Sea. There we need a dockyard, but that is still to come.

In the Mediterranean there has been a notable increase in the fighting strength of the British fleet, as though to indicate to lukewarm friends and possible foes that, in spite of all the sacrifices of the South African war, in spite of the far calls of the Empire, Great Britain is still able to maintain, with greater show of power than ever before, her historic rôle of supreme mistress in the tideless waters. Some years ago French journalists used to refer to the Mediterranean as "the English lake." It never merited that sobriquet more than to-day, when fifteen armoured ships,—two armoured cruisers and the remainder battleships,—are there flying the Union Jack and the White Ensign, ten of them the most powerful and modern afloat.

The forces ready for the defence of the vital sea-interests of the British Empire may be indicated as follows, and the comparative figures of 1897,—six years ago,—will show the growth which has taken place, not in ships rotting in dockyards, but in vessels at sea, fully manned and stored, with their magazines replete with powder and shell and the war heads prepared for the torpedoes; ships, in short, ready for war:—

MEDITERRANEAN SQUADRON

1897	1902
38 ships of all classes	58 ships of all classes
Battleships (10)	*Battleships* (13)
Anson.	Bulwark.
Barfleur.	Cæsar.
Camperdown.	Canopus.
Hood.	Formidable.
Nile.	Illustrious.
Ramillies.	Implacable.
Revenge.	Irresistible.
Rodney.	London.
Royal Oak.	Ramillies.
Trafalgar.	Renown.
	Repulse.
	Vengeance.
	Victorious.
Cruisers (11)	*Cruisers* (13)
2 first-class	2 first-class (1 armored.)
5 second-class.	6 second-class.
4 third-class.	5 third-class
8 gunboats.	4 gunboats.
5 "destroyers."	20 "destroyers."
1 torpedo-ram (Polyphemus.)	1 old ironclad (Rupert.)
1 old ironclad (Rupert.)	1 torpedo depotship (Vulcan)
5 ships of no fighting value.	6 ships of no fighting value.

CHANNEL SQUADRON

1897	1902
12 ships of all classes	12 ships of all classes
Battleships (7)	*Battleships* (6)
Empress of India.	Hannibal.
Magnificent.	Magnificent.
Majestic.	Majestic.
Prince George.	Prince George.
Repulse.	Jupiter.
Resolution.	Mars.
Royal Sovereign.	
Cruisers (5)	*Cruisers* (6)
2 first-class	2 first-class (2 armored.)
2 second-class.	2 second-class.
1 third-class.	2 third-class.

It is understood that additional battleships will shortly be detailed to this squadron, giving it a strength of eight battleships.

HOME SQUADRON

1897	1902
	Battleships (10)
As a Squadron it had no real existence. The ships wer only partly manned and at sea one month a year.	Resolution.
	Royal Sovereign.
	Nile.
	Revenge.
	Anson.
	Camperdown.
	Empress of India.
	Sans-Pareil.
	Benbow.
	Collingwood.
	Cruisers (4)
	2 first-class (armored.)
	2 second-class.
7 torpedo gunboats.	7 torpedo gunboats.
16 torpedo-boat destroyers.	28 torpedo-boat destroyers.
(At the three home ports.)	(At the three home ports.)

Two second-class battleships, the *Edinburgh* and *Devastation*, and two of the third-class, the *Hero* and *Conqueror*, are in reserve, manned, together with three old armored cruisers, the *Immortalité*, *Undaunted* and *Narcissus*, but of little fighting value.

CRUISE SQUADRON

1897	1902
	Cruisers (8)
This Squadron did not exist. The four ships of the training squadron, the *Active*, *Calypso*, *Champion* and *Voylage* were absolutely useless for fighting.	Good Hope (armoured.)
	Drake (armoured.)
	Minerva.
	Hyacinth.
	Brilliant.
	Rainbow.
	Medea.
	Medusa.

In the course of the coming year this squadron will be further strengthened by substituting four armoured cruisers of the *Kent* type for four protected cruisers.

These are the forces which are in commission for defending the "Narrow Seas." They comprise the following ships of fighting value:—

Battleships	29
Cruisers, first-class	8
Cruisers, second-class	14
Cruisers, third-class	9
Gunboats	11
Torpedo-boat destroyers	48
	119

The increase in the number of ships and the necessity for more systematic training for officers and men has called for an augmentation of commanding officers and staff. The principal officers of these squadrons comprise the following, entirely new appointments being indicated by asterisks:—

MEDITERRANEAN SQUADRON

Admiral Sir Compton Domvile.
Rear Admiral Custance. C. M. G.
*Rear Admiral Sir Baldwin Walker (for command of cruisers.)
*Captain the Hon. Stanley Colville, chief of Staff of Commander-in-Chief.
*Captain W. de Salis (for command of the torpedo-boat destroyer flotilla.)

CHANNEL SQUADRON

Vice Admiral Sir A. K. Wilson, V. C.
Rear Admiral the Hon. A. Curzon-Howe.

HOME SQUADRON

Vice Admiral Sir Gerard Noel.
*Rear Admiral Atkinson-Willes.

CRUISER SQUADRON

*Rear Admiral W. H. Fawkes.

HOME PORTS

*Captain C. G. Dicken as Inspecting Captain of "destroyer" flotillas.

To summarise:—What has been accomplished?

1.—In home waters a practically new fighting squadron (the Home) has been created, which makes Portland its rendezvous.

2.—Another new squadron, a flying squadron (the Cruiser), with two of the

GETTING OUT TORPEDO NETS ON THE "SANS PAREIL"

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latest and most powerful armoured cruisers and six protected cruisers for use where required has been constituted.

3.—The Channel squadron has moved its headquarters from Portland to Berehaven. This place has been strongly defended, and is the best strategic point of rendezvous for the two probable scenes of action, namely, the Mediterranean, giving a clear and secret run down to Gibraltar; and the northern exit from the North Sea by way of the north of Scotland.

4.—The Mediterranean squadron has been strengthened, in view of any change in the naval attitude of other powers.

5.—The cruisers in the Mediterranean have been placed under a flag officer for definite training in their own peculiar duties in war.

6.—The torpedo flotilla in the Mediterranean has been quadrupled, and has been placed for specific training under a captain, an expert student of torpedo warfare.

7.—The commander-in-chief in the Mediterranean has been given a captain who has no ship to occupy his thought, but devotes himself to assisting the Admiral in the organisation of the fleet and the observation of the trend of naval affairs in the Mediterranean.

8.—The torpedo flotillas round the south and east coasts of England have been strengthened and also placed in charge of a captain.

It may naturally be asked,—How far have other Powers strengthened their hold on the "Near Seas," and is British supremacy secured by these measures?

In the latest edition of Jane's "All the World's Fighting Ships" an attempt has been made to assess the fighting value of the squadrons of the several Powers, and as the system adopted has met with the approval of Admiral Sir John Hopkins, among others, the result is of some interest, though it appears, on casual observation, too flattering to Great Britain. All the vessels have been reduced to the common denomina-

tion of 1, and the conclusion as to the relative value of the squadrons in the Mediterranean, the Channel, the Baltic, and the Black Sea, of Great Britain, France, Russia, and Germany,—no account being taken of Italy,—is:—

Great Britain.	France.	Russia.	Germany.
30.8	15.2	4.7	7.8

Probably these figures in the actual rough-and-tumble of a battle would prove far from reliable as an index of strength; but regarded as the result of a theoretical analysis of the figure of merit possessed by the fleets in actual commission of the various Powers, they are of interest, and, if somewhat discounted, serve a purpose in supporting the conviction that in the "Narrow Seas" Great Britain is, for the present, outside the zone of extreme danger; but France, Russia and Germany have, proportionately to their strength, more ships in reserve. Not ships alone, but training and position will count in war. This is why all paper calculations must be considerably discounted.

Great Britain has not been unmindful of the trend of international friendship and jealousy. The disposition of the British fleet in the "Narrow Seas" indicates that vigilance has been shown. The naval authorities have done their task quietly, remembering the advice, —Treat your enemy as though he may become your friend, and your friend as though he may become your enemy. In view of increasing activity on the part of Great Britain's neighbours in naval construction, renewed watchfulness is necessary in the future. Assuredly the country that does not go forward in these days of rapid naval expansion will go back. There is no standing still and apparently no finality.

WORKING PEOPLE'S HOMES

WHAT IS BEING ACCOMPLISHED BY AMERICAN BUILDING AND LOAN ASSOCIATIONS

By D. A. Tompkins

THAT country is always the most prosperous whose workpeople have the best home life. Home life conduces to the highest wages, the best education and training, and the greatest prosperity of a nation and of all its people.

The writer has worked as a machinist, as a designer of machinery in the draughting room, as master machinist, and in conducting a business of erecting industrial works on his own account. In each of these occupations he has found the " home " or " local " building and loan association of invaluable service, and its exacting, but fair, requirements have been of inestimable advantage to him.

When I was a machinist the building and loan association afforded me an opportunity for regularly saving a portion of my pay. While working for wages, and, later, when receiving a salary, I accumulated a little capital, and was always getting an enforced training in economy and promptness. The condition imposed by the association, of regular and prompt payment of dues or submission to a fine, made just enough coercion to enforce upon me the habit of regular savings and prompt payments. Since I entered upon business on my own account the shares which I have carried in the building and loan associations have ever given me a feeling of security in the consciousness of holding a reserve fund. Once or twice I have had occasion to make use of this resource at times when I might otherwise have been more or less embarrassed.

Being much impressed with the advantages of the building and loan system for the people of any community, I have in this article endeavoured to exhibit these advantages, as I have seen them, for the benefit of other working people.

The most successful and most advantageous system of savings for working people is that of co-operative institutions, whereby the people may help themselves and make their own way to prosperity. One of the most important conditions necessary for the successful maintenance of such an institution is the development of intelligence and skill by education and training. The development of intelligence rests upon the system of education provided by the State. The execution of the system is in the hands of the teachers; the development of skill rests upon the system of industry or labour fostered by the State. The execution of the system rests, in industrial pursuits, with the employer and the workman; in agricultural pursuits, with the farmer. Wherever this condition is well fulfilled, human labour, when aggregated, is a most excellent basis of credit.

At some time in the past somebody discovered that human life, when taken in the aggregate, is a good collateral,—a good basis of credit. Upon this theory, with proper regard for surroundings of industry and economy, life insurance companies have been formed, and, from very small beginnings, have accumulated vast wealth. Nothing is

A SPECIMEN OF WHAT HAS BEEN BUILT FOR $1500

more uncertain than the life of one individual. Nothing in human affairs is more certain than the average life of, say, 5000 men having normal surroundings.

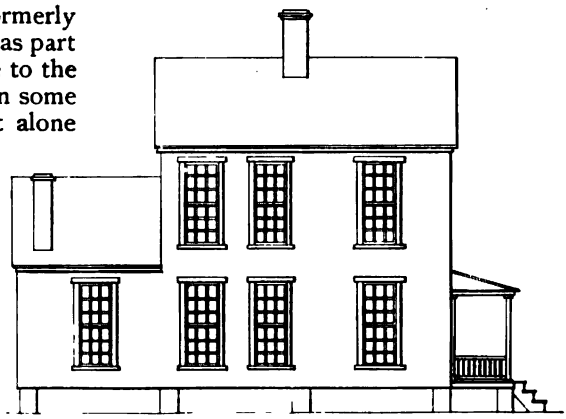
So, also, an agreement with one workingman is an uncertain basis of credit. One workingman might be dishonest, might lose his job, might get ill, or might die. Five hundred or a thousand workingmen together, however, have a certain average condition of continued work and pay. If one drops out, another can take his place. This makes the very best basis of credit, superior to all other forms of security.

All accumulated property, except land, is the result of past labour. Even land would have no value except for labour. Buildings depreciate; they become old and obsolete. Corporate securities are uncertain and hazardous. Even land itself depreciates under changed conditions. But the labour of a country is always in the most modern form, and of the fullest value. Current labour,—the labour of to-day, labour in the aggregate,—when its uncertainties are eliminated, ranks, as a basis of credit, above the very best of other forms of collateral.

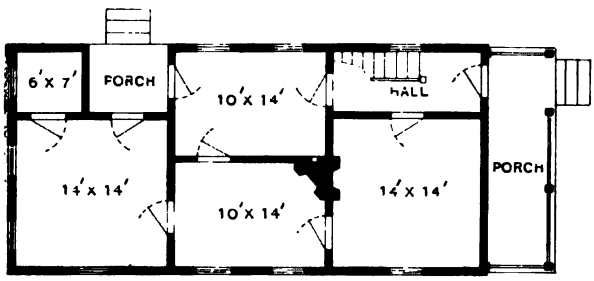
A building and loan association is an institution for aggregating and averaging the net results of labour and establishing it as a basis of credit. To illustrate its operations, assume that 500 people form an association. They may be machinists, bricklayers, merchants, clerks or telegraph operators,—all working people, and all having fair prospects of regular employment, for wages or salaries. If each member pays in $1 a month, these 500 people will save an aggregate of $500 a month. In two months the association will have $1000. This sum may be used to build a house for one of the members. The house is deeded to the member for whom it is built. The association retains a mortgage on it to insure payment of dues and interest until each other member, in turn, gets a house. This usually requires regular payment for about six and a half years. The member moves into

his new house. The rent formerly paid is now saved, to be applied as part of the dues and interest payable to the building and loan association. In some cases, when rent is high, the rent alone will pay dues and interest. In such cases rent money literally buys a home. In all cases the rent money pays a large portion of the instalments. At the worst, a very small additional outlay is required for a home of comparatively high value.

Where houses are rented, in half the cases the rent money will pay half the cost of the house in about six and a half years. In a quarter of the cases the rent money will pay three-quarters of the cost; and again in a quarter of the cases the rent money will pay all the cost. These differences depend on the cost of building, the rates of rent, and the discretion and taste of the member who builds.



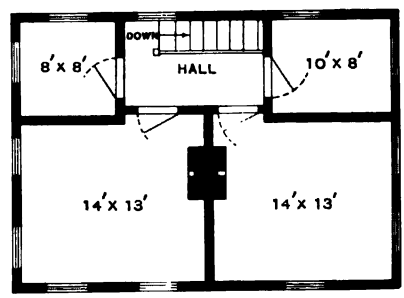
A $525 COTTAGE WITH SIX ROOMS AND KITCHEN



FIRST FLOOR PLAN

The membership of building and loan associations has been drawn mainly from industrial wage-workers. It is, however, by no means confined to this class. The membership of most associations includes also merchants, professional men, teachers, preachers, and, in some cases, also capitalists and farmers.

The plan of organisation is, briefly, as follows:—A charter is obtained and by-laws are prepared. Subscription lists or subscription blanks are provided; sometimes both. An admission fee of 25 to 50 cents per share is usually charged, to pay for charter, cost of books, stationery, and expenses connected with organisation. The payments are usually fixed at 25 cents a week, or $1 a month, per share. It is best to make the payments by the week, with provision for those who prefer to pay by the month. In most cases from 500 to 1000 shares are subscribed for before business is begun. Associations are sometimes organised and put into operation with no more than 100 shares subscribed. This would give an income of about $100 a month. To accumulate $600 to lend to a member to build a modest house would thus require six months. It would be necessary in such a case for officers to serve practically without pay. Yet a small beginning, like this, has been made in many cases, and the organisa-



SECOND FLOOR PLAN

tion, under careful management, has grown into a large and important institution.

In all cases the money is loaned to members as fast as it is accumulated, in such sums as they may desire, and on the approval of the board of directors, or of a credit committee of the board. A first mortgage is taken on the property on which the borrowed money is spent. Loans to the extent of about two-thirds to three-fourths the value of the property are usually considered safe. If the borrower owns a plot of ground he can generally get enough money to build the house. If a member has no ground plot, he may find somebody willing to sell one on long time and take a second mortgage, provided the first mortgage is given to the building and loan association to secure a loan for building a house on the lot.

Land companies, and individuals trading in land, are often willing to sell a lot on these terms. When the payments to the building and loan association are completed, say in six and one-half years, its debt and mortgage are cancelled, and then the second mortgage, made for the cost of the lot, becomes the first. But, if desired, money may now be borrowed from the building and loan association, on a new series, to pay off this original debt on the lot. The advantage of this is that the debt is finally cancelled by the easy payments to the building and loan association, whereas it might be irksome to pay it all off at one time.

The best form of building and loan association would seem to involve the following points:—

First.—It should be local.

Second.—Its intervals of payment should be suited to the usual manner of income of its members.

Third.—Its rules as to prompt and regular payments should be rigid, and should be rigidly enforced.

Fourth.—Its shares should be $100 par value, and the interest rate 6 per cent.

Fifth.—Loans should be made in the order of application for them, and should be made at the par value of $100 a share, without discount, bidding, premium, or reduction of any kind.

Close association is a sharp spur. People living in the country where families are considerably separated are never so attentive to neatness as those who live in towns and cities. The influence of doing things jointly, too, is always strong. Association with a number of other people, many of whom one knows and is likely to meet at intervals in social life or in business, rarely fails to stimulate the individual to his best endeavours to do his part in any organisation as well as the average, or better. Club members usually regard club dues as a first debt to be paid.

The moral influence of local and social association has its effect upon the officers of an organisation, as well as on the members. Where the members have easy access to the officers, and meet them in daily life, the opportunity and the temptation to do wrong are minimised. Here, again, is seen the effect of aggregated influences. The officers are encouraged and constrained to do right by the elbow touch of the entire membership.

The co-operative savings institution, to be successful, must be of a kind that aggregates the strength and influence of its members, and it must also be so situated that this aggregate influence is always upon its officers, thus constraining in them the greatest circumspection, and constraining each member to the highest degree of effort to keep himself straight with his association. In local institutions the consciousness of oversight stimulates each member to keep his property in good shape, pay his dues and interest with unfailing regularity, and be sober, industrious and economical.

The system may be varied in many ways, as to payments, fines, and other regulations, to suit different conditions; but the aggregation feature, in some form or other, must always be preserved. The meaning of this is, that the great bulk of the members must know one another, or at least be near enough together to attend meetings in case of trouble; and that loans must be made

only on property so situated that it may be readily visited by an examining committee, and may, if occasion requires, be inspected and passed upon by the bulk of the members. This means that this sort of savings and loan association the county lines would usually enclose a territory that would be "local" within the meaning intended.

Membership need not be rigidly re-

A HOUSE WITH FOUR ROOMS AND KITCHEN. COST, $900

all the property taken for security must be within a limited local area, say a city or a township, and that most of the members must live within this area. The character of a member who borrows is an important element in the security of the loan. It, as well as the mortgaged property, ought to be under the observation of the members.

These considerations establish the first condition above named,—the successful building and loan association must be local. Any limit is suitable within which people are likely from time to time to see something of one another. Ten miles is of little consequence to a farmer, who has facilities for the trip and has the habit of travelling more or less over the country, while for a machinist it would be both inconvenient and unusual to go into the country to inspect property. It would not be advisable for an association made up of workers in industrial pursuits in a town or city to take farm property lying at a distance in the country. In such an association property accepted for security must be in the town or city and the immediate vicinity. If farmers should undertake stricted to locality. Most of the members should, however, come from the territory in which the securing property is to be taken. Indeed, the purpose of the association is that home people may save home money to buy houses to live in, or to do business in; or that they may lay by something against a rainy day, or to make old age comfortable, or to raise and educate a family of children.

Many so-called building and loan associations have been formed on plans that were totally lacking in the essential features of co-operation. These spurious institutions are made up of members widely scattered, few of whom ever see the officers. It stands to reason that the very scattered condition of the members of such institutions prevents co-operation, and most of them have failed.

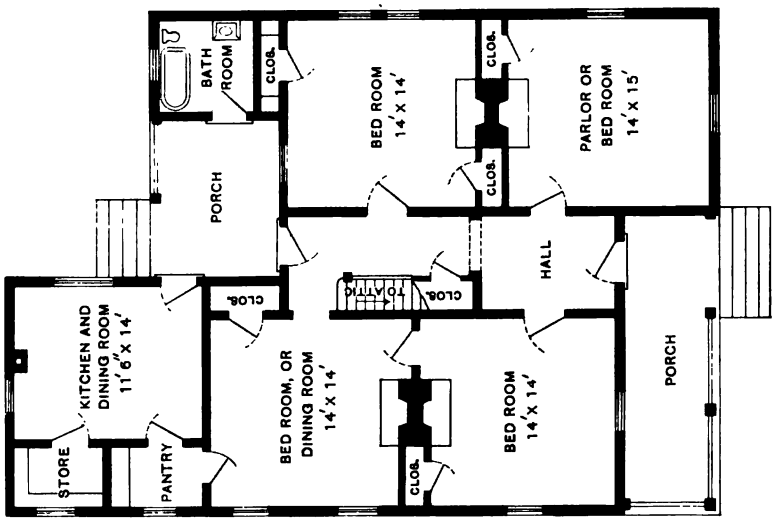
The next important condition for a successful association is that regular and prompt payment be secured. To this end, the times of payment should be fixed to correspond with the usual pay days at the various works, stores, and other institutions in the town or city. An association of farmers would naturally

fix their instalments to suit the marketing of their crops, having them come quickly on the heels of their principal sales. Whatever the appointed times of payment, strict observance of them should be rigidly required.

Most of us need just a little pressure to make us do fairly by ourselves in the matter of husbanding the fruits of our labour. Working people are usually rather liberal and generous, and there is always a crowd of human parasites that live on the labour of others. If the savings institution would succeed among workingmen, it must shape its rules so that they may and must pay in their money before these parasites can get it. Once satisfy the member that the instalments paid in are safe, and to his own account, and he is willing enough to pay in his money whenever he has it; but if he must wait long, or even if he may wait long, his money is likely to go before he knows it, and in ways that are unaccountable even to himself. It is important, therefore, to make the instalments suit pay days, to fix a fine to enforce payment, and to be strict in requiring that payments be prompt. It is not desirable to be so inflexible in the enforcement of rules as to cause hardship; temporary failure to pay on account of unavoidable accidents, or sudden and temporary sickness, should be judiciously overlooked occasionally. This should be done, however, only in special cases.

The plan of bidding for loans, though not so disastrous as that of scattering the members, is very undesirable. By this plan the money is loaned by auction, as it were. Whoever bids to accept a loan at the greatest discount gets it. Sometimes the bid is 5 per cent. discount, or "premium," as it is called. Sometimes it is 10 per cent., and even more. As much as 40 per cent. has been known to be bid. This is taking advantage of the needs of members in a very unfair way. Where two men want money, it would be much better to accommodate both without discount, and in the order of their application. Some associations have had a fixed discount or "premium."

By far the best way is to have applicants for loans listed in their order, and to assign accumulated money, in regular order, and at par, according to the list. By knowing the rate of income of the association and the aggregate of applications ahead, any one applicant can be told with approximate accuracy when he can get the money applied for.



FLOOR PLAN

Knowing this, he can easily make his arrangements, without being harassed, as he might often be, if bidding had to be done to get a loan.

The building and loan association is

FRONT ELEVATION OF A $400 COTTAGE WITH THREE ROOMS AND KITCHEN

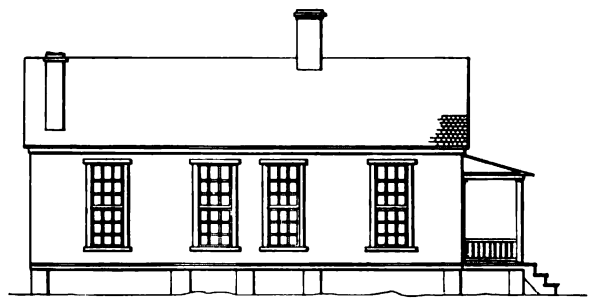
not, even in its best form, a primrose path to fortune. It affords simply an opportunity to those who, in its absence, might despond and be lost. It does nothing for the man or woman who is unwilling to try.

It makes a great difference whether the operations of a building and loan association are conducted in a growing town or in one that is retrograding or standing still. In a progressive town rents are high. Therefore, in such a town rents will come nearer paying dues and interest on a loan to build a house than in a town that is not progressive.

To the individual the opportunity is simply a question of getting wages. Even in a slow town, and at cheap rent, a family would be better off to join an association and build a house for themselves. Many a time the first dawn of awakening and prosperity for a town has been due to the act of the working people in the organisation of a building and loan association. When working people abandon rented houses and apply their wages to payments on houses of their own then capitalists are compelled to make investments in enterprises that make more occupation, more wages and more wealth.

While working as a machinist, and in other capacities, for the Bethlehem Iron Company, in Pennsylvania, I saved money enough to buy a lot. I joined a building and loan association, and borrowed money enough to build a house on the lot. The par value of a share was $200. I subscribed for and borrowed on seven shares, making a mortgage debt of $1400 at 6 per cent. interest. The dues on the shares were $7 a month, and the interest ($1400 at 6 per cent.) was $7 more. This made $14 a month I had to pay. It required about ten years for the stock to mature and bring the shares to the par value of $200. I rented the house for $15 a month. While I had to pay $14 a month for ten years to own the house, the tenant paid me $15 a month, and at the end of ten years he owned none of the property he had paid for.

I owned a lot of about 75 feet frontage in Charlotte, N. C., with one negro cabin on it. I reconstructed the cabin



SIDE ELEVATION

to make a neat workingman's cottage, with two rooms and a kitchen. I built two other similar cottages, each on 25 feet of the lot. The reconstruction of the old cabin into a cottage cost $100. The new cottages cost me $250 each. I borrowed $600 from the building and loan association. This required six shares, at $100 each. Dues were $6 a

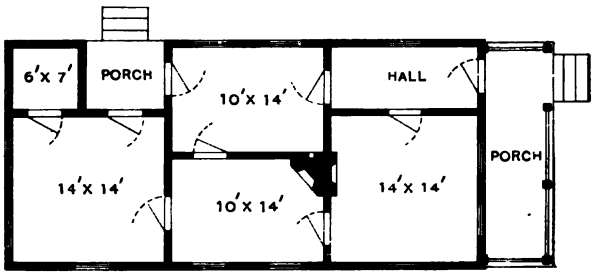
month. Interest at 6 per cent. was $3, making $9 a month. The houses rent for $4 a month each. I pay out $9 and collect $12. In six and one-half years the tenants pay for the cottages for me, and pay me a surplus besides.

In both the above cases there are some expenses, such as insurance, taxes, and repairs, which have not been taken into account. Both are rather exceptional and favourable cases. But even when rent money can be made to pay for a house, a man will sometimes figure long to show that a bank loan at simple interest is cheaper than a loan from the building and loan association.

Even when an ordinary loan can be made, the differential cash advantage of it over the building and loan method is of small consequence. The main difference is that the building and loan plan leads the borrower gently, easily, and surely out of debt. If it is a home he has built, his mortgage is being every week reduced, and will certainly be cancelled at the end of the term of the series. By any other plan of borrowing, maturities of debt and interest are far apart. Interest alone becomes a lump sum, and unless it has been accumulated by instalments at home it is hard to pay; deficiencies soon bring discouragement, and by discouragement many a house is lost and goes to the money lender, and he is blamed for what is no fault of his. The trouble is that the workingman has no means of making regular small payments on his debt, at intervals when he has the money, and, in the absence of any pressure to accumulate it, he spends it.

It is not intended to argue that there are not conditions under which it is as well, or even better, to borrow from commercial banks or individuals. This discussion relates to a plan for serving advantageously a large proportion of working people and people engaged in commerce in a modest way. The tremendous success of these associations leads one to the conclusion that 90 per cent. of all the houses built through them could never have been built by borrowing money and making an ordinary mortgage to a money lender, bank or individual; or if they had been built, more than one-half would never have been paid for by the purchasers. The great advantage of the building and loan association lies in the instalment payments and the little coercion to compel regularity.

The advantage is greatest for working people living in houses of moderate size and cost. This is not because the landlord is extortionate. Small cottages, frame or brick, are necessarily more perishable than larger and more expensively built houses. The average tenant refuses to make repairs that he could well make. He always makes the landlord spend money. Therefore, the landlord must get rent enough to pay for repairs. Thus the tenant pays in cash for something that he could as well do without and would do without if he owned the house.



FLOOR PLAN OF THE COTTAGE SHOWN OPPOSITE

Besides repairs, the workingman can make improvements often without cost. The owner of a property always finds economical means to better it. In this lies much of the advantage of the building and loan association. It requires a man to own his property before it will deal with him at all, except as a stockholder and saver of money. The building and loan association is perfectly willing to advance the money necessary for a man to buy or build, but it will not consider such a thing as buying property to be held for rent to its members.

In the two examples cited it actu-

A ROW OF TYPICAL WORKING PEOPLE'S HOMES IN PHILADELPHIA

ally cost the owner of the land no money to buy houses. In the great majority of cases the rent will not pay all the interest and dues. Sometimes, where the rent is $10 a month, it will take $15 to pay dues and interest. Meantime, one is living in one's own house rent free. Sometimes, when rent is $20, the interest and dues for a $2400 loan would be $35 a month. The variations are innumerable. To save disappointment, each individual must figure out for himself the case he has under consideration. Some cases are more favourable, and some less; but I have not met with any case in which it did not pay a workingman to join a building and loan association, quit renting, build a house, and apply rent money toward paying for it.

The building and loan association always requires that a man own his lot. Then it will lend money to build a house, taking a first mortgage on the whole property. Many a workingman reflects that for a man without a lot the plan is impracticable. That conception is a mistake. There are almost always opportunities in a town for a workingman to buy a lot on long credit, with the privilege of building a house on it with building and loan money, giving a first mortgage to the building and loan association and a second to the landowner. At first blush, this would seem indiscreet on the part of the landowner. On consideration, however, almost any landowner, and all the land-developing companies, will do this. Every payment made to the building and loan association is a reduction of the first-mortgage claim. Therefore, soon after the start the second mortgage is perfectly safe. At the end of about six and one-half years ($100 shares) the first mortgage is paid off, and the second mortgage becomes the first.

Thus a workingman may, on the basis of his sobriety, honesty and industry, buy a lot on credit, build a house on credit, and pay for the house in about six and one-half years, through the building and loan association, keeping up the interest on the lot debt. Then he can transfer the lot debt to the association and pay it off in about six and one-half years more. This takes twelve and one-half to thirteen and one-half years,—a long time. That is true; but reflect that the start was with nothing, and the end was the ownership of a house that otherwise never would have been owned.

Aside from the question of building a house, or serving as security for a business, building and loan shares are good investments, and the plan is the very best for savings. Every young man could with advantage carry a few shares. It will astonish him to find how his savings will increase with regular forced payments.

The profit or interest averages about 7 per cent. This varies with the actual rate of interest charged borrowers, which is usually 6 per cent. It also varies with the expense of conducting an association, and with the amount of fines imposed and collected.

In subscribing for shares without loans no serious obligation is assumed. There is generally, and should be always, provision for withdrawal of cash paid in, with some little interest, after the series has been in operation for more than two years. The amounts paid for expenses for the first two years or more are usually at least as much as the accumulated interest for those two years on the small sums paid in. With this provision, if the wage-earner of a family should die, the membership in the building and loan association is a benefit, and no disadvantage. Any accumulated money is an advantage to the widow and children regardless of interest.

Sometimes there is hesitancy because of a possibility of moving. The membership is no hindrance to moving. The money paid in can be withdrawn, or, better still, it may be left standing, and the payments to the building and loan association at the old place may be kept up from the new home.

In addition to the profit shown in figures the home-builder makes other gains, which show themselves in better citizenship and better life:—

1.—He puts himself in position to utilise his spare time for his own ad-

ELEVATION OF CITY HOUSE, FIVE ROOMS AND KITCHEN. COST, $1400

vantage. Improvements which he can make on the house are all his.

2.—Flowers, trees, and vines planted are all his own, and he can take more interest in these adornments if they are his rather than his landlord's. This, perhaps, ought not to be so, but it is so.

3.—It raises him in the esteem of his neighbours to become the owner of his house. This brings him better opportunities.

4.—It settles him in a house and raises him above the status of the transient workman, both in his own estimation and in fact. His self-esteem being stimulated, he is at once a better man.

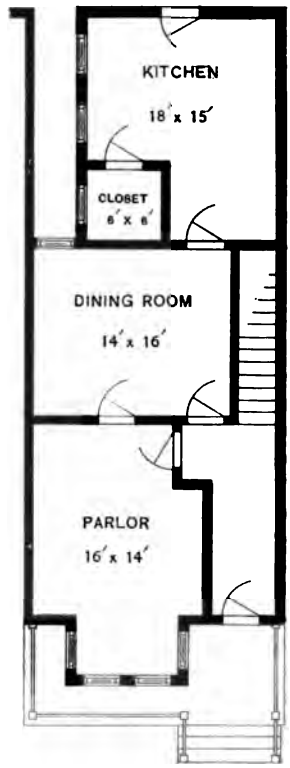
5.—Having a home, he learns loyalty to his town and patriotism to his country.

Taking safety into consideration, the interest or profit is usually more than a workingman can get on regular savings from any other source. In addition to this profit, the workingman gets the opportunity to shift his rent money to the payment of a house for himself, and, in some cases, the rent money actually pays the whole dues and interest or the whole cost of the house. In such a case the profit is 100 per cent., aside from the fact that in many cases the workingman's savings are all profit, because the money would have been spent had not the periodical pressure of the building and loan association caused him to save it.

The value of a beginning to save is often, in itself, the equivalent of a fortune. One frequently hears a successful man attribute his success to some incident that induced him to begin saving.

The workingman who owns his home has made the conditions that are necessary to free him from the harassments of strikes and squabbles for increased wages. By home study and self-improvement he can learn to do better work at higher pay. A weaver of plain goods can, by learning to do Jacquard work, double his pay quicker than he could ever get 10 per cent. advance by a strike. How much better to make substantial headway by peaceful means rather than make scant headway by violence and trouble!

Besides the material, moral, and in-



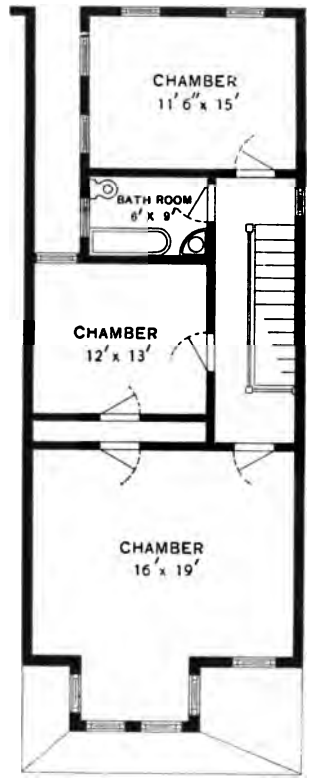
FIRST FLOOR PLAN

tellectual advantages of home-building, already cited, there is an æsthetic and artistic advantage. The workingman who owns his home may take pleasure in planting flowers, in making a pretty plot of grass, in planting trees and shrubs, and in otherwise improving the beauty of the home. Many a child is born to working parents who has taste and talent for art, music, painting, tapestry weaving, etc. In the conditions that often surround working people in rented houses and hovels, any superior talent or taste of a child or youth is dried up.

One of the most astonishing things in the writer's experience with building and loan associations and with working people is the contrast of conditions at Charlotte, North Carolina, the writer's place of residence. Part of the working people live in their own homes, and are the equals, if not the superiors, of working people in any other section. These are the machinists, carpenters, bricklayers, and workers at several other trades. They send their children to school, and have all the attributes of good citizenship. Another class, the cotton mill operatives, in many cases live in company houses, move frequently, save little money, and give scant attention to schools. Many of them are as good citizens as working people who are in other occupations; but in the main the difference between their condition and that of the former class of work people is enough to be notable. It is equally notable that the machinists, carpenters, and bricklayers are extensive patrons of the building and loan association, while the cotton mill operatives are not. Sometimes it is claimed that the wages of the cotton mill operative are too low to admit of saving; but this is an error, as the income of the average cotton mill family is greater than that of the average machinist or carpenter. In a cotton mill several members of a family can work, while the carpenter alone of his family is a wage-earner.

A similar contrast exists in Pennsylvania. The Philadelphia mechanics, for example, are usually members of building and loan associations, and live in homes which they own through these institutions. On the other hand, the coal miners live usually in company houses, and are inclined to strikes and squabbles.

No matter whether the membership in the building and loan association is the cause of the better living or whether



SECOND FLOOR PLAN

the disposition to live better is the cause of the membership,—the advantages of membership are apparent. It appears also that a community of working people who are saving their money and building homes are rarely engaged in any kind of controversy with their employers, and are practically never engaged in strikes. The ownership of a home by parents leads to better attendance at school by the children, and to steadier industry by all. It is soon learned that by increase of knowledge and skill far better advance in wages

A ROW OF $1200 COTTAGES AT CHARLOTTE, NORTH CAROLINA

can be gained than by strikes. It is learned that education and training are the cheapest things in the world to buy, and the highest-priced things in the world to sell.

Working people have rarely raised wages more than 10 per cent. by means of strikes. By improving one's knowledge and increasing one's skill, wages may be doubled, tripled, or even further increased. The first step for a working man's family towards education and skill is the saving of money to buy a home. It is in and from the permanent home that the best education and the best training can be acquired. Philadelphia has been called a city of working men's homes. It is notable that Philadelphia has a population of high-priced and contented working people. They build the ships and locomotives, weave the lace curtains and carpets of America, and do a lot of other high-class work at high wages. They commenced early to save their money, build homes, and educate their children.

Illustrations are given in these pages of examples of houses, of various design and cost, such as are most commonly built by working people through the building and loan associations, in different parts of the United States.

In studying economies of house building, let no one think he can safely dispense with the services of an architect. If a bricklayer wants carpenter work done, he had better hire a carpenter to do it than attempt it himself. If a machinist wants bricklaying done, he had better get a bricklayer to do it. The architect is trained in making a house cheap and beautiful, as the mechanic is in doing a good job at his own trade. He can reduce expense at one point and add much to beauty at another, and the net cost of employing him will be little or nothing.

Yet with the opportunity to build houses for themselves, there is no more fruitful source of good ideas than the working people themselves. The husband is usually a mechanic of some kind, machinist, bricklayer, carder, weaver, or some other. He can give good ideas about construction. The wife usually does her own housework, and she can give good suggestions as to location of doors, windows, kitchen equipment, and other things.

The writer, while working for the Bethlehem Iron Company, in Pennsylvania, frequently had occasion to make drawings for working people who built homes through the building and loan associations. The designs of these houses were usually made up of ideas furnished more by the mechanic and his wife than by the draughtsman. Indeed, the wife had the most to say about it, and the mechanic and the draughtsman generally did as she said. By this process of engaging the interest of the mechanic in the design, a standard type of workingman's home was soon developed. This is a two-story brick building, with parlour, dining-room, and kitchen on the lower floor, and with two or three bedrooms and a bathroom on the second floor. Block after block of these houses has been built in the Lehigh valley, in Philadelphia, and in Baltimore. Illustrations of these are given on pages 608, 610 and 611.

The building and loan association gives a solution of the problem of working people's homes that is most essentially advancement by self-help. It is a plan by which working people themselves solve the problems of betterment for themselves. There is nothing philanthropic about it. It is business, pure and simple. The man or woman who joins a building and loan association and builds a house sacrifices nothing of self-respect, and nothing of dignity. Indeed, self-respect and dignity are increased.

The mechanic who builds a house, sends his children to school, and otherwise identifies himself with a community of good people, has an important advantage over the one who comes to-day and may go to-morrow. He becomes a citizen, a neighbour, and a friend, where before, even though a good mechanic, and well thought of, he had no particular standing in any community. His better situation makes better opportunities for his children. Identification with a community and its people

always makes a better condition for any family. The home, and the binding of the family to the community, are largely the basis of Anglo-Saxon strength and Anglo-Saxon civilisation.

There is no help for working people that compares with the help they provide for themselves. Munificent philanthropy is as nothing compared with a morsel of self-help. The one may be fruitless, or even injurious; the other is always strengthening and fruitful.

Working people have far more resource and ability to pay their own way, and to pay for what they get, than is generally supposed. Indeed, most of them pay extravagantly for what they get. In many cases they pay enough rent for a cheap and uncomfortable house to pay, in a very few years, for a good, comfortable house, and own it in fee simple. It is the opportunity to do this latter thing, rather than financial help, that they need,—even if the help is called philanthropic or semi-philanthropic. The greatest mistake of the philanthropist is usually judging others by his own tastes or ideas. He too frequently fails to give either support or sympathy to what the workingman wants to do, but he insists that the workingman shall do as the philanthropist wants him to do.

Laws and conditions that place opportunity within the reach of the workingman himself, and for himself, do more good for his advancement than all actual contributions in money or advice that could possibly be made. All humanity can be brought to lose courage and heart by being given no chance. There are so many ways by which working people are cheated out of, or otherwise deprived of, savings, that many a one is brought to feel that he had rather squander his surplus earnings than put them where he might likely lose them for the advantage of somebody else. With a knowledge, however, that what is saved is safe for himself, the workingman becomes a capitalist.

It is rare that a workingman needs charity, or any kind of free help. Make for him a fair opportunity and good security for his savings, show him the opportunities, convince him that they are safe, then give him friendly encouragement, and the chances are he will succeed. But to do so he must be left perfect freedom to undertake something according to his own tastes, and not be pressed into doing something that somebody else thinks he ought to do. Good advice is all right, but it is all wrong to press on the workingman methods of spending his earnings and savings that are contrary to his tastes and what he considers his requirements.

Good philanthropy for the workingman is, more than all else, opportunity and freedom.

SOME ABNORMAL BRITISH LOCOMOTIVE TYPES

By Charles Rous-Marten

IT may fairly be said, I think, that the steam locomotive first assumed its normal form and shape in the year 1837,—sixty-five years ago. In that year the Great Western express engine "North Star" was built by Messrs. R. Stephenson & Co. at their Newcastle works. That engine is still on view at the Swindon Works, and anybody who takes the trouble to travel thither and inspect it will agree with me that it approaches in a surprisingly close degree the normal shape and style of many modern single-wheel locomotives; indeed, of some that have been built even within the last few years.

Even allowing for the various changes in respect of minor details that may have been made during "North Star's" career of thirty-three years,—the engine having been withdrawn from service in 1870,—the similarity in general design between this original "No. 1" of the Great Western, sixty-five years ago, and some engines which came out at the extreme end of the nineteenth century, will at once strike any observer. The illustration on page 616, which differs but little from sketches and photographs that are extant of "North Star" in the days of her zenith, strongly corroborates this judgment.

It is true that as regards some dimensions she fell short of the modern standard. With cylinders only 16 inches in diameter and a piston stroke of 18 inches to drive 7-foot wheels, and with only 724 square feet of heating surface to furnish the motive power, she contrasts forcibly with the latest type of modern 7-foot single-wheelers, the No. 10 class on the Great Eastern Railway, which has 18-inch cylinders, 26-inch piston stroke, 1292 square feet of heating surface, and a leading bogie. But if we take the 6-foot single-wheelers of the South-Eastern, and the 6-foot 6-inch Great Northern "Hawthorns," built in the fifties; the 6-foot 6-inch of the Midland, and the 7-foot of the Great Northern in the sixties; the Great Western 7-foot of the seventies and eighties, there will be found a continuous similarity of type, and while other standard engines, built between 1837 and 1902, may differ in many points of detail, they will almost all be found to bear a strong resemblance to "North Star" in main features of general design.

But it was not long before the abnormal began to make its appearance. And, curiously enough, it was on the Great Western, which had been the earliest of all constructed railways to adopt a locomotive type that was really satisfactory all round.

But from this straight highroad of prevalent uniformity in main design

FIG. 1.—ORIGINAL NO. 1 ENGINE ON THE GREAT WESTERN RAILWAY, BUILT IN 1837. THIS PRACTICALLY ESTABLISHED THE STANDARD GENERAL OUTLINE OF LOCOMOTIVES

PHOTO BY F. MOORE

there soon began to appear occasional bold departures in the way of abnormal types. I do not purpose now to enter into too elaborate a description or analysis of the numerous "freak engines" which have come out at one time and another during the past three-quarters of a century—each as quite "the last word" in respect of locomotive merit—only to meet with speedy condemnation and an early grave in the scrap-heap. My intention rather is to touch upon several specially interesting and plausible variations from the normal which merit at least consideration and a respectful hearing.

So early in railway history as the year 1838 two remarkable locomotive monstrosities were designed and built for the Great Western Railway. Then, as now, an idea existed in the minds of many people that the one main requisite for the attainment of high speed was an enormous driving wheel. There is much plausibility in this notion, because it is unquestionable that the larger the wheel, the less the wear and tear at high speeds. Unfortunately, this is only one of the many factors which need to be taken into account, and probably all the advantage that may accrue from the increased size of a driving wheel is at least counterbalanced, if not heavily overbalanced, by the material loss of relative tractive force which unavoidably accompanies every addition to driving wheel diameter

However, those were the days of railway infancy, and, I may add, ignorance. The Great Western had already employed driving wheels 8 feet in diameter, and Mr. T. E. Harrison, C. E.,—afterward distinguished as the able Engineer-in-Chief of the North-Eastern Railway, —having to design new express engines for the Great Western, resolved to "go two better" and add 24 inches to the wheel-diameter that had been the largest hitherto, – to increase it from 8 feet to 10 feet. The locomotive was built at Newcastle-on-Tyne by Messrs. R. & W. Hawthorn, and was named "Hurri-

cane," Fig. 2. With 16-inch cylinders, 20-inch piston stroke, and only 624 square feet of heating surface, it will readily be perceived how feeble and ineffective the new engine would be, possessing only forty-two pounds of tractive force for every pound of effective steam pressure in the cylinders, not more than six tons adhesion weight, and very small steam pressure. But it had other drawbacks.

Another fallacy which obtained in those early days was that a high-pitched boiler was disadvantageous, if not absolutely dangerous. With the driving axle 5 feet above the rails and a 10-inch crank-throw, the under side of the boiler barrel must have been at least 6 feet above the rail level,—allowing for the space occupied by lagging, etc.,—and so, with a boiler 4 feet in diameter, its axis would have stood fully 8 feet above the rails. Nowadays 8 feet 6 inches to 9 feet is deemed a perfectly safe height even on the narrower 4-foot 8½-inch gauge; but not so in 1838, and, therefore, special provision had to be made for the 10-foot driving wheels. This was accomplished by placing the boiler on a separate frame from that to which were attached the cylinders and the leading, driving, and trailing wheels. So, as the boiler-frame was placed on six wheels, this eccentric locomotive ran on no fewer than twelve wheels, only one pair being employed for purposes of propulsion. It hardly needs to be said that this monstrosity proved an immediate and final failure, and was never able to do any actual train work.

But the ingenious Mr. Harrison had yet another string to his bow. He designed and built, simultaneously with "Hurricane," a second locomotive named "Thunderer," Fig. 3, which also had its boiler on an independent frame, but had two pairs of coupled 6-foot driving wheels connected with the second frame, these being geared up three to one with the view of rendering them practically equivalent to a single pair 18 feet in diameter. Had the four 6-foot coupled wheels been placed under the boiler in the usual way, "Thunderer," even with cylinders only 16 × 20, and 624 square feet of heating surface, might have proved a fairly useful machine as locomotives went in those days. As it was, her thundering was as mild as the force of the other's hurricaning, and the fastest journey made by either engine was to the scrap-heap, which was reached in double-quick record time.

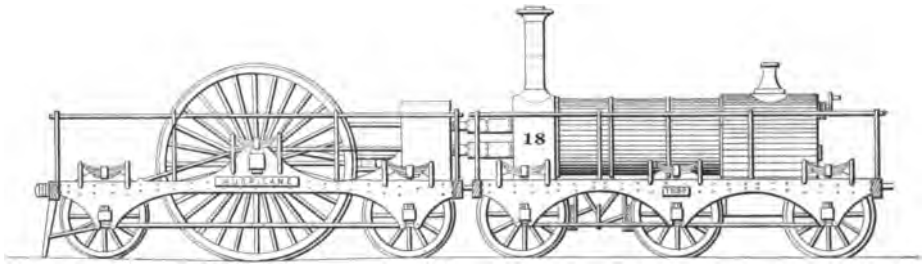


FIG. 2.—THE "HURRICANE," BUILT IN 1838, WITH 10-FOOT DRIVING WHEELS. THE BOILER WAS PLACED ON A SEPARATE FRAME FROM THAT TO WHICH THE CYLINDERS, LEADING, DRIVING, AND TRAILING WHEELS WERE ATTACHED. THE ENGINE WAS NEVER PUT TO ACTUAL SERVICE

REPRODUCED, BY PERMISSION, FROM STRETTON'S "DEVELOPMENT OF THE LOCOMOTIVE"

After these peculiar divergences from the normal the Great Western, under the able guidance of Brunel and Gooch, turned out for several years a series of excellent 7-foot, single-driver locomotives, which, like their pioneer "North Star," closely resembled in appearance and general idea most modern single-wheelers, differing from these merely in dimensions and minor details, one of the latter consisting in the use of the domed or pyramidal erection over the fire-box.

In 1846 Sir Daniel (then Mr.) Gooch brought out his 8-foot single class, of which "Great Western" was the first and "Lord of the Isles,"—in 1852,—the last to be put to work, this type being maintained and actually doing the principal express duty on that important line until 1892, only ten years ago, when, the 7-foot gauge being abandoned, they became useless and were broken up, one survivor only, "Lord of the Isles" itself, remaining, and being preserved with the No. 1 engine of 1837 at the Swindon Works, as a curiosity.

But the success of "Great Western" immediately inspired rivalry, and, as might have been anticipated, that rivalry found its exponent in a fresh case of the abnormal,—a new monstrosity. The Great Western engine had 8-foot wheels, so, of course, Mr. F. Trevithick, who burned to bring out a London & North-Western engine that should beat it into fits, must needs have a wheel 8 feet 6 inches in diameter. And here again came in the nervousness about a high-pitched boiler, just as this dread had led to the building of the "Hurricane" monstrosity. Mr. Trevithick shuddered at the bare idea of putting a boiler above the axle of an 8-foot 6-inch wheel. He did not feel compelled to follow the Great Western lead of 1838 and put it on a separate frame. So he decided to hang it below the driving axle. The result was the famous engine "Cornwall," which was shown in the Hyde Park International Exhibition of 1851. It is illustrated on page 621.

Certainly "Cornwall" was a locomotive of a class very different from "Hurricane." With 17½-inch cylinders and 24-inch piston stroke, and a fair-sized boiler, as boilers then went, she had unquestionable capabilities up to a certain point, and she actually did regular work in her original shape for a period of fifteen years, displaying exceptional capacity for high speed. But the design was manifestly awkward and inconvenient, and the type was never reproduced. About the year 1862 "Cornwall" was rebuilt by the late Mr. J. Ramsbottom, with a new boiler placed above the axle in the customary way, and as thus rebuilt she has run for forty years on light

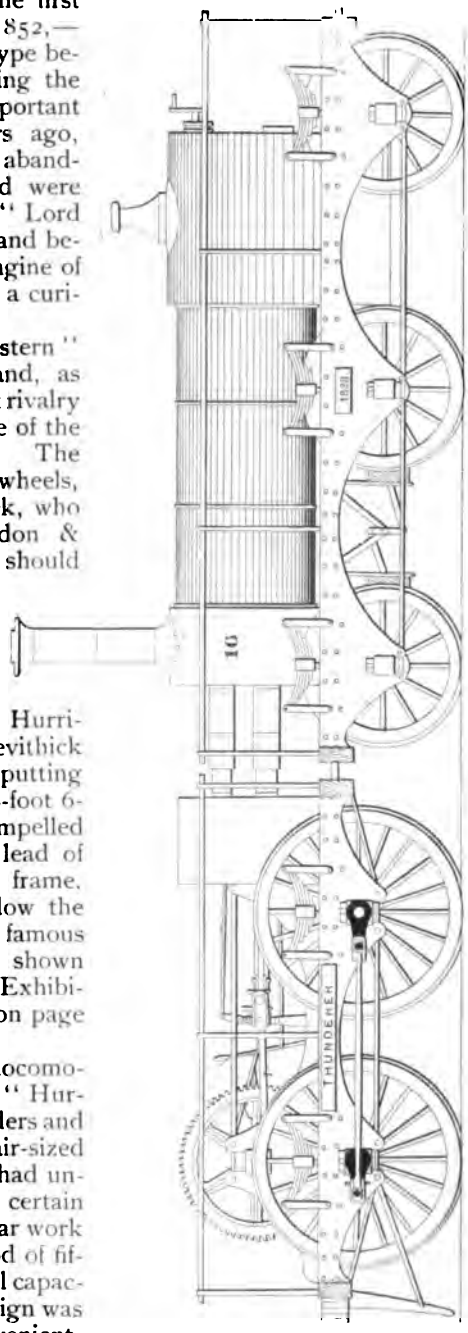


FIG 3. THE "THUNDERER," 1838. THE BOILER HERE, TOO, IS ON AN INDEPENDENT FRAME. THERE ARE TWO PAIRS OF COUPLED 6-FOOT DRIVERS, GEARED UP 3 TO 1, MAKING THEM EQUIVALENT TO A PAIR OF 18-FOOT WHEELS. BUILT, BUT NOT USED IN ACTUAL SERVICE

REPRODUCED, BY PERMISSION, FROM STRETTON'S "DEVELOPMENT OF THE LOCOMOTIVE."

expresses. I myself have had several capital runs with her in recent times. Not long since she brought up to Euston a "Boat Special" from Liverpool, and she seems still equal to light duty for some years. Manifestly, however, she is not the "Cornwall" of abnormal type which came out in 1847, but an engine of normal design (Fig. 4), peculiar only in having the biggest driving wheels in the world.

Just as the Great Western in 1838 had brought out two abnormalities simultaneously, so did the London & North-Western some ten years later. About the same time as "Cornwall" appeared to amaze the world Mr. T. R. Crampton devised a locomotive named "Liverpool," which, as well as "Cornwall," was exhibited at Hyde Park in 1851. Its peculiarity consisted mainly in its very low-pitched boiler being carried by six small wheels, while the axle of the single pair of 8-foot drivers was placed immediately behind the fire-box, the cylinders, 18 inches × 24 inches, being placed outside the framing and between the second and third pairs of carrying wheels. This engine, having a really large boiler, with no less than 2290 square feet of heating surface,—too much, however, for the cubic capacity of the boiler barrel,—was a fairly powerful engine for that period in respect of load hauling, and is stated to have done work equal to the aggregate of three of the other London & North-Western engines then in use, while she is said to have attained, with light loads, a speed as high as that achieved either by "Cornwall" or "Great Western," viz., 78 to 79 miles an hour, although the records on this head are somewhat vague. It seems certain, however, that this "freak" engine was enormously superior to the others already mentioned, viz., "Hurricane," and "Thunderer," and "Cornwall" in her original form. The chief faults found with her were undue weight on the light rails at that time used, and the long, rigid wheel-base presented by the eight wheels without a bogie.

But Mr. Crampton produced, about the same time, several other abnormal types. Two were also for the London & North-Western, one ("London") having 8-foot single drivers and cylinders 18 inches × 20 inches, and 1529 square feet of heating surface, while the other ("Namur") was a smaller and six-wheeled variant of "Liverpool," and had 7-foot single drivers, placed behind the fire-box. See Fig. 6. He also had one built with two pairs of 6-foot 6-inch driving wheels, driven, not directly from the connecting-rod, but by coupling rods from a "dummy" crankshaft which was turned by the connecting-rods from the pistons. These two last-named types are of special interest, inasmuch as they had important developments both in England and abroad; indeed, they connect that period even more directly than does the old "Cornwall" with wholly modern times.

For the "Namur" Crampton type, although it met with only limited adoption at home, obtained large favour abroad. Many of these engines have been running for half a century in France, and some are still at work on the French Eastern Railway, one having been rebuilt by M. Salomon, the able Ingénieur-en-Chef of that important line, with a Flaman double boiler, similar to those with which his very fine express engines, Nos. 801-840, are fitted. Thus rebuilt and reboilered, one "Crampton" is reputed to have attained the highest speed ever reached on the European Continent until lately, viz., 144 kilometers, or 89 miles, an hour, which has been only slightly exceeded very recently by one of M. du Bousquet's magnificent ten-wheeled engines of the "Atlantic" type, on the de Glehn four-cylinder compound system, one of which I tested on the French Northern Railway at 145.2 kilometers, or 90.3 miles, an hour.

The other eccentricity,—that of employing an intermediate crankshaft to receive the motion from the piston and connecting-rod, and to convey it to the two or four driving wheels by means of outside cranks and coupling rods,—had a very interesting development in England. The original engine, which had

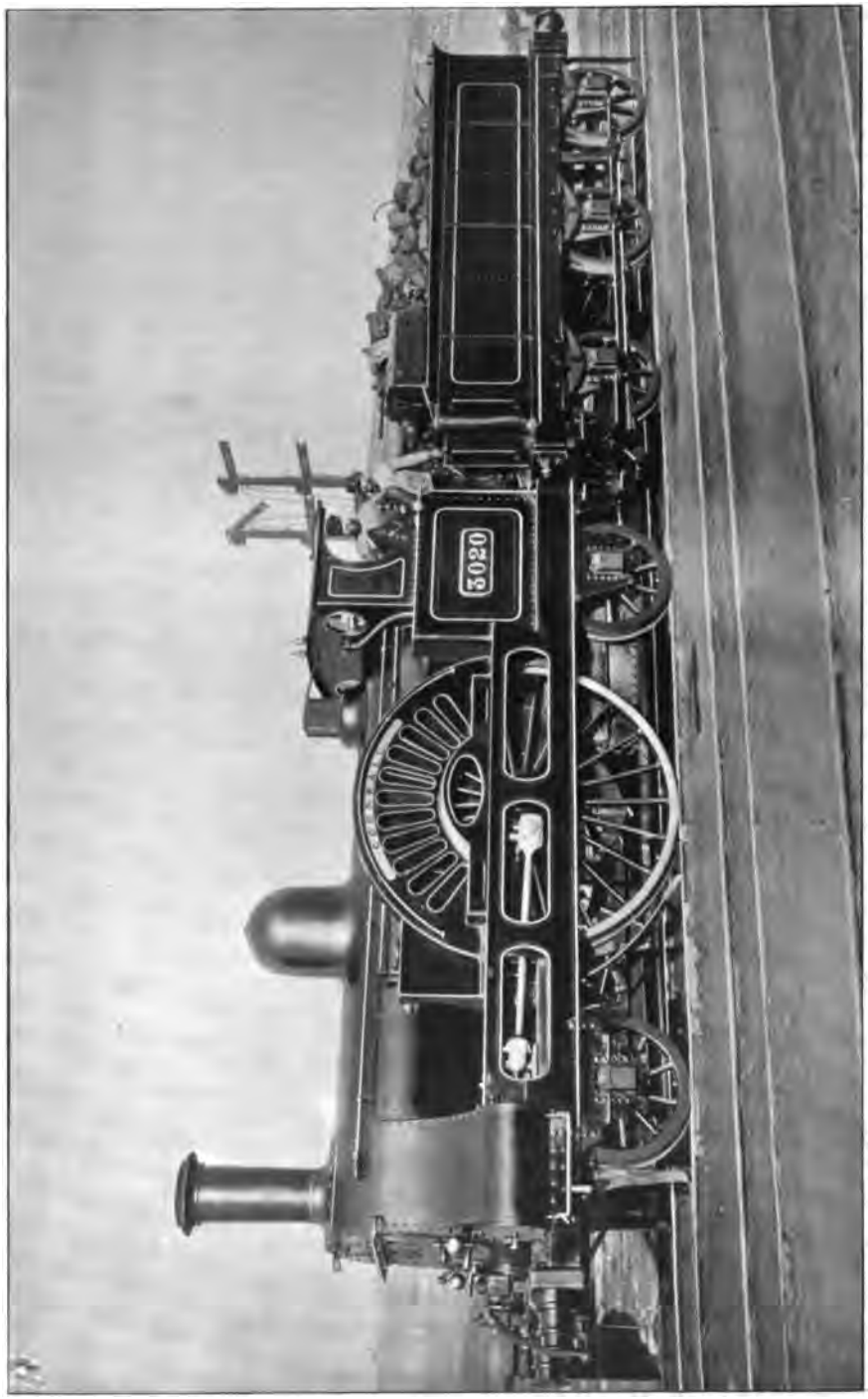


FIG. 4.—THE RECONSTRUCTED LONDON & NORTH WESTERN EXPRESS ENGINE "CORNWALL," WITH 8-FOOT 6-INCH DRIVING WHEELS. IN SERVICE FROM 1863 TO 1896. THIS LOCOMOTIVE, FOR HER TIME, HAD THE LARGEST DRIVING WHEELS IN THE WORLD

about sixteen tons on each axle, was soon condemned as too heavy. A smaller one was built, and this was taken over by the North-Eastern Railway, where it did a good deal of work as a tank engine. See Fig. 7. But the chief developments were in the single-wheeler form. Mr. Crampton placed two pairs of carrying wheels under the leading end of his new engine, and the driving wheels behind the fire-box, as in all his other single-wheelers. But he left a large space between the drivers and the second pair of leading wheels, and in this space he fitted a dummy axle or crankshaft which was driven direct from the inside cylinders and drove the driving wheels by means of coupling rods from outside cranks on the dummy axle.

Various advantages were claimed for this design, which, however, was ultimately condemned. But meanwhile it had "caught on" largely. In the Exhibition of 1851 one of these Crampton engines, built by Messrs. R. Stephenson & Co., of Newcastle, for the South-Eastern Railway, and named "Folkestone," was shown. See Fig. 9. It was one of a batch of eight, numbered in the "130's," which for some years did the best express work on the South-Eastern Railway, but were, in the end, converted into coupled engines by putting wheels on the dummy axle or crankshaft, while one pair of leading wheels was done away with. In their original form, nevertheless, with 6-foot single driver sand cylinders 15 inches × 22 inches, they did some excellent service.

Shortly before they were all converted I noted a run with one drawing twenty-one of the four-wheeled coaches of the period from London Bridge to Redhill. It passed New Cross (3 miles) at a speed of 45 miles an hour, in five minutes from the start, and the rate did not fall below 30 miles an hour up the succeeding 2½ miles at 1 in 100. This was clearly creditable. Another, on the up express from Dover, took twenty-four of the small coaches from Redhill to London Bridge, ascending the first 2 miles of 1 in 264 to the Merstham tunnel in five minutes, and attaining 60 miles an hour down the subsequent easy descent toward Croydon.

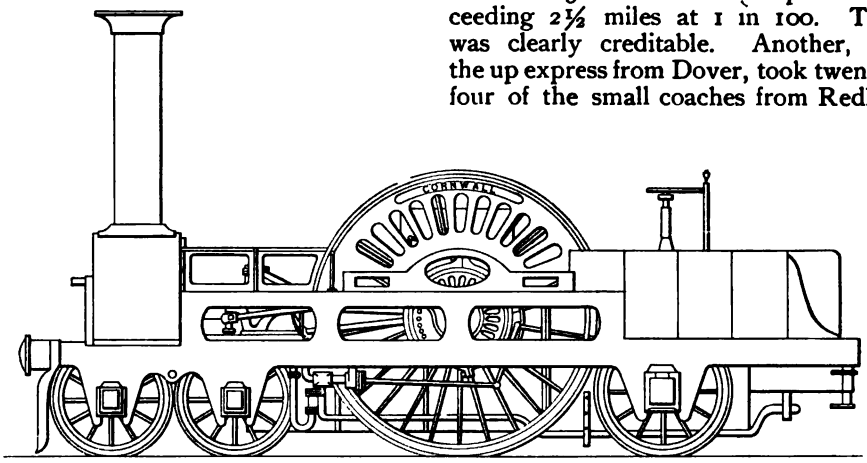


FIG. 5.—THE ORIGINAL "CORNWALL" ON THE LONDON & NORTH-WESTERN RAILWAY. BUILT IN NOVEMBER, 1847, AND RUNNING IN THIS FORM TILL 1862

REPRODUCED, BY PERMISSION, FROM STRETTON'S "DEVELOPMENT OF THE LOCOMOTIVE"

Another development of this abnormal type was still more interesting. Ten of a like class were built by Longridge & Co. for the Great Northern Railway in 1850, and were numbered 91–99 and 200. They had 6-foot 6-inch drivers behind the fire-box, and cylinders 16 × 21, with two pairs of leading wheels with intermediate dummy axle or crankshaft. That arrangement, however, was speedily condemned by Mr. Archibald Sturrock, the able and progressive locomotive superintendent of

FIG. 6.—EXPRESS ENGINE ON THE CRAMPTON SYSTEM, WITH THE DRIVING AXLE BEHIND THE FIRE BOX. THIS TYPE OF LOCOMOTIVE IS STILL IN USE ON THE EUROPEAN CONTINENT

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that period, who rebuilt them as ordinary single-wheelers with leading and trailing carrying wheel. In their rebuilt form they were among the finest and most successful express engines of their day.

I remember one of them (No. 94) taking a fast train of sixteen coaches from Hatfield to Holloway, 16¼ miles, in twenty-one minutes net from start to stop, ascending the first 5 miles to Potter's Bar in nine minutes, and then maintaining a steady 60 to 65 miles an hour until speed was reduced for the stop. Some of these excellent engines, as rebuilt, continued at work for nearly forty years, and were scrapped only in comparatively recent times.

A third case in point was that of the London, Chatham & Dover, which had five Crampton engines of this type among its earliest express locomotives. Nos. 27-31 had 6-foot 6-inch drivers behind the fire-box, inside cylinders 16 × 22, and dummy crankshaft like the others. They had one great improvement, however; the four leading wheels were placed in a bogie-frame, thus giving immensely enhanced freedom of running, through the shortening of the rigid wheel-base. But the plan did not long meet with favour, and the engines were all rebuilt as eight-wheelers with two pairs of 6-foot 6-inch wheels coupled. The leading bogie was retained, and all of these engines were running until very lately; two or three are still at work.

Deficient adhesion weight was the drawback chiefly alleged against the "Folkestone" type of Crampton engine. It is not easy, however, to see why this should not have been overcome had the arrangement been convenient in other respects. Probably it would be more accurate to say that the plan itself was needlessly complex and in various respects troublesome, especially as to maintenance, without possessing any counteracting special merits. And so it has long disappeared.

One of the abnormal plans tried during the forties and early fifties was that known as the Stephenson "Long-Boiler" type. With a view to averting the waste of heat revealed through

the excessive temperature in the smoke-box, Mr. Robert Stephenson adopted a boiler length of 13 to 14 feet, and to avoid undue extension of rigid wheel-base, he placed all the wheels under the boiler barrel and in front of the fire-box. In the case of single-wheelers the small trailing wheels were sometimes removed to the rear of the fire-box, this involving an extreme length of rigid wheel-base, which, however, was found preferable to the "tail-wagging" movement resulting from the large overhang of the fire-box. In other cases the driving axles were moved back close to the fire-box front and the trailing pair of carrying wheels was placed between the drivers and the leaders.

Many engines were built after this plan and others were thus altered. In some instances a third pair of carrying wheels was added behind the fire-box, thus producing the same arrangement as was first introduced in the case of Sir Daniel Gooch's "Great Westerns." Instances of this plan were the old "97" Class on the Eastern Counties, —now Great Eastern,—and some London & North-Western engines. The long-boiler locomotives, single, four-coupled and six-coupled,—six-wheeled and eight-wheeled,—were built in large numbers at one time and did much good work, becoming practically included among the normal standard types; but the system was found disadvantageous in various respects, and they mostly disappeared nearly forty years ago.

Another abnormal departure taken in the early fifties also possesses interest. It was inspired by the advent of the London & North-Western "Cornwall," which, having the largest driving wheel in the world, 8 feet 6 inches in diameter, had relatively dwarfed the Gooch 8-foot and 7-foot 6-inch singles, of which the broad-gauge railways, the Great Western and the Bristol & Exeter, were so justly proud, besides claiming to hold the speed record. So Mr. Pearson, the Bristol & Exeter Locomotive Superintendent, designed a new express engine, which was unique not only in having single driving wheels no less than 9 feet in diameter, the largest ever yet used in actual practice, but also in running on ten wheels, including leading and trailing four-wheeled bogies, and having

FIG. 7.—NORTH-EASTERN TANK ENGINE, WITH INTERMEDIATE CRANK SHAFT OR DUMMY DRIVING AXLE

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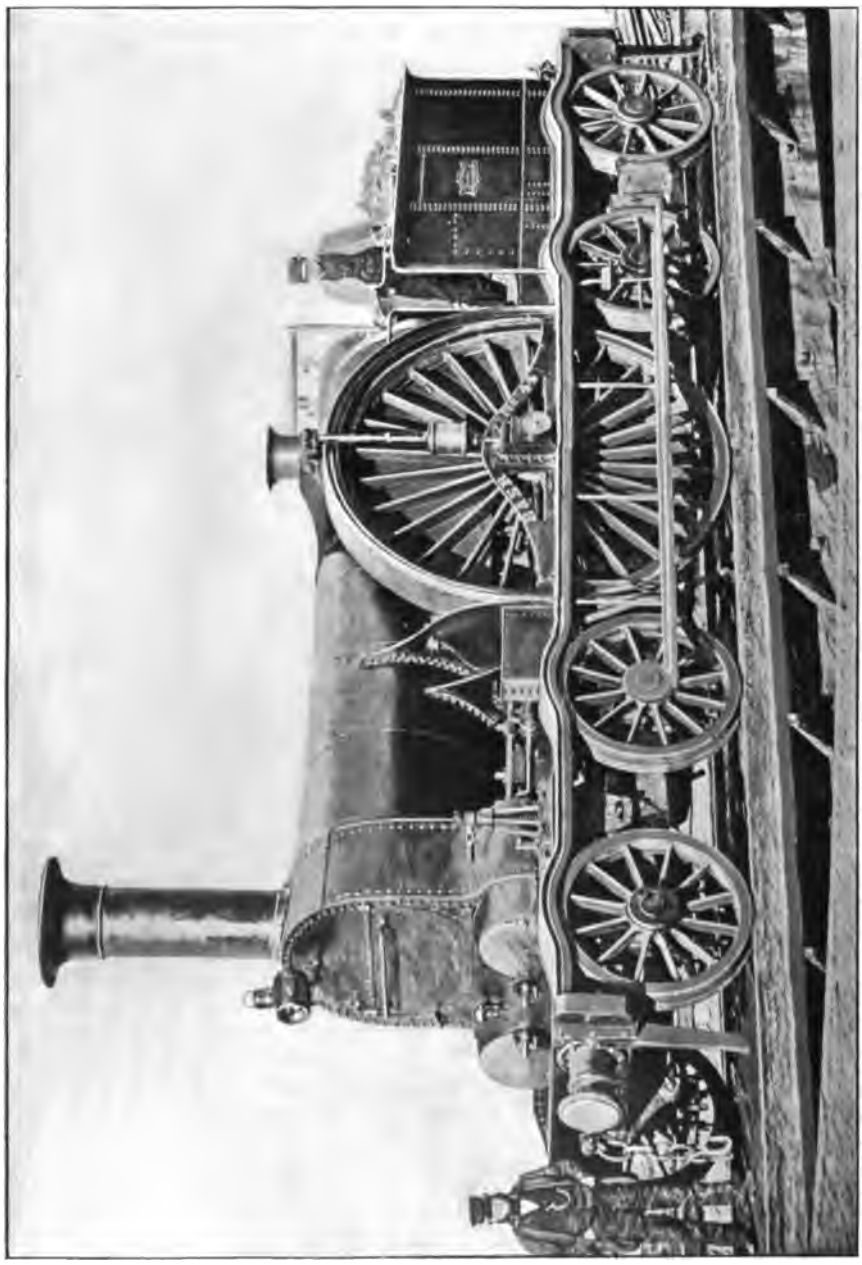

FIG. 8.—AN EARLY SINGLE-DRIVER EXPRESS TANK ENGINE ON THE BRISTOL & EXETER RAILWAY. THE DRIVERS ARE 9 FEET IN DIAMETER, THE LARGEST EVER PUT INTO SERVICE. THE WATER WAS CARRIED IN TWO TANKS SLUNG UNDER THE BOILER. ONE OF THESE ENGINES IS OFFICIALLY REPORTED TO HAVE RUN A MILE IN 44 SECONDS, OR AT THE RATE OF 81.8 MILES AN HOUR

no tender. It was, in fact, a tank-engine, albeit of wholly abnormal design, the water being carried in two tanks slung under the boiler. The cylinders were originally 16½ inches × 24 inches, and the boiler had about 1600 square feet of heating surface. This engine is shown in Fig. 8.

These remarkable locomotives, of which eight were constructed, acquitted themselves admirably with the light expresses of that period, and are noteworthy as being the first ever built which were authentically tested as having attained speeds of 80 miles an hour and upward. On one occasion, indeed, one is officially reported to have run a mile in 44 seconds, or at the rate of 81.8 miles an hour, down the Wellington bank.

When the Great Western absorbed the Bristol & Exeter line four of these peculiar locomotives still remained and were taken over, being renumbered 2001-2004; but No. 2004 left the rails at high speed at Long Ashton, near Flax Bourton, owing to the disturbing influence of her underhung tanks when one was empty and the other full. She was totally wrecked, and the other three were rebuilt as standard tender-engines with 8-foot drivers, cylinders 18 inches × 24 inches, and one pair of trailing wheels, the leading bogie being retained. Nos. 2001, 2002 and 2003, as rebuilt, did capital work until the 7-foot gauge was abolished in 1892.

It is noteworthy that during an inspection of the British railways which I made in the years 1884-1885 under the auspices of a colonial government, one of these engines attained the highest speed I recorded during that period, viz., 81.8 miles an hour, which was the same as that officially reported to have been attained by the same engine as above mentioned thirty years previously and at exactly the same spot, down the Wellington Bank. The coincidence is interesting.

Yet one more abnormality of the "fifties" deserves notice. Impressed with the desirableness of getting rapidly out of the way the heavy mineral traffic which the Great Northern, after its extension to London, speedily developed, Mr. A. Sturrock conceived the idea of enabling his mineral engines to haul longer and heavier trains by increasing their tractive power with the aid of the tender wheels. He accordingly fitted his tenders with a pair of small cylinders,—supplied with steam from the engine boiler,—and coupled the six wheels. That he obtained by this method a valuable increment of strength at relatively small cost, there is no doubt at all. And the engines with steam tenders did, I am informed, excellent work as long as they received fair play. But the drivers resented having to take heavier loads at the same rate of pay, and as their views were not met by the authorities, they did not give the engines a fair chance. One of these engines is shown in Fig. 10.

Various complications arose, and ultimately the plan was abandoned. I am not aware that it has been tried again; but I am convinced that it possesses considerable potentiality of usefulness, and I expect to see it again adopted sooner or later. Indeed, it is within my own knowledge that an ex-locomotive superintendent of specially varied experience is strongly in favour of the plan and would himself try it, did the opportunity offer. For the present it is regarded, I think unjustly, as a failure of the past.

At this stage,—because it will not fit in conveniently elsewhere,—I may notice briefly, in passing, one abnormal design which came out a good deal later on one of the railways now incorporated in the North-Eastern system. I refer to the 7-foot coupled express engines built by Mr. W. Bouch, with leading bogies and 17-inch outside cylinders. The peculiarity of these engines consisted in their having a piston stroke no less than 30 inches in length. This, undoubtedly, enhanced their tractive force; but it did not meet with general approval, and on the engines of the "1270" class coming into the hands of the North-Eastern Railway, they were rebuilt with the stroke 4 inches shorter. Their original length of piston stroke is, of course, quite abnormal in

FIG. 9.—AN OLD EXPRESS ENGINE ON THE SOUTH-EASTERN RAILWAY, "FOLKESTONE" TYPE, CRAMPTON'S PATENT, WITH INTERMEDIATE CRANK SHAFT

British practice, although not so in America. It has been revived during the current year in the case of the new Great Western six-coupled express bogie engine No. 100, which has cylinders 18 inches × 30 inches. It remains to be seen whether this new departure will become a feature of ordinary practice. See Figs. 11 and 12.

Upon the whole, there was little of abnormality among the locomotive types that came to the front in the sixties and seventies. By a steady process of evolution the coupled express engine which had made a temporary and sporadic appearance in 1855 in the shape of Sir D. Gooch's 7-foot coupled "Abbot" class on the Great Western,—once again the pioneer of a new course,—steadily developed itself after its sudden introduction on the Midland by Mr. M. Kirtley in 1862, until in the eighties it seemed about to become wellnigh universal.

From the outside-cylinder single-wheeler "Snake" type, introduced by Mr. J. V. Gooch in 1842 on the London & South-Western, with its outside cylinders 15 inches × 21 inches, and its 6-foot 6-inch drivers, had become evolved the similar, but improved, "274" class on the Great Eastern, and their successors, Mr. R. Sinclair's "290" class of Great Eastern 7-foot single-wheelers, Mr. Connor's "Caledonian" 7-foot and 8-foot single-wheelers, and Mr. P. Stirling's famous 8 foot singles on the Great Northern, with their outside cylinders, 18 inches × 28 inches, which may be said to have had a sort of first cousins in the 7-foot 6-inch single-wheelers with outside cylinders, placed by Mr. Massey Bromley and Mr. C. Sacre on the Great Eastern and the Great Central lines, respectively.

The inside-cylinder single-wheeler had likewise expanded from the "North Star" of 1837 and the "Jenny Linds" of the forties into the "157" and "1120" classes of 7-foot singles, and Mr. W. Dean's Great Western singles with 7-foot 8-inch wheels; Mr. A. Sturrock's 6-foot 6-inch "Large Hawthorns" on the Great Northern; and Mr. P. Stirling's successive 7-foot and 7-foot 6-inch singles on the same railway, into Mr. W. Stroudley's 6-foot 6-inch singles on the London, Brighton & South Coats Railway; into Mr. S. W. Johnson's 7-foot 4-inch, 7-foot 6-inch and 7-foot 9-inch singles on the Mid-

land; into Mr. Worsdell's 7-foot and 7-foot 6-inch single-driver compounds on the North-Eastern, and Mr. J. Holden's "770" class of 7-foot singles on the Great Eastern. And finally, just when it seemed likely that no more single-wheelers would be built, there sprang up, at the extreme end of the nineteenth century, two brand-new classes, viz., Mr. H. A. Ivatt's "261," set on the Great Northern with 7-foot 6-inch wheels and cylinders 19 inches × 26 inches, and Mr. H. Pollitt's Great Central type, with 7-foot 9-inch wheels and cylinders 19½ inches × 26 inches, while Mr. Johnson brought out yet another batch of his 7-foot 9-inch Midland class with larger fire-boxes and double-bogie tenders, all these last mentioned being thoroughly up to date in their details.

FIG. 10.—GOODS ENGINE ON THE GREAT NORTHERN RAILWAY, WITH ARCHIBALD STURROCK'S STEAM TENDER

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One cannot, in these circumstances, class the single-wheelers as "abnormal," even though latterly they have constituted a distinct, if large, exception to the prevalent trend of locomotive practice in Britain, the universal rule in Europe, and the universal, with one exception, in America. It is more accurate to classify the modern British single-wheeler as the greatly less-numerous of two main types. But the abnormal has been by no means lacking in recent years. When Mr. F. W. Webb brought out his first three-cylinder compound "Experiment" in 1882, she was undoubtedly a complete departure from the normal. But almost before she had been fully tested she was multiplied by thirty and followed by a larger variant to the number of forty more, and these by yet another thirty of three different sub-classes. And as those one hundred express three-cylinder compounds have been succeeded by sixty four-cylinder express compounds, and more than one hundred compound good engines, some three-cylinder, some four-cylinder, have been built by Mr. Webb for the London & North-Western alone, it is evident that, on that line, at any rate, the compound has become the normal type among all modern London & North-Western engines.

But the four-cylinder non-compound engine "Jubilee," built also by Mr.

FIG. 11.—NORTH-EASTERN BOGIE EXPRESS ENGINE, WITH 7-FOOT COUPLED WHEELS AND 17 × 30-INCH CYLINDERS. THE ONLY BRITISH EXPRESS ENGINE TO HAVE 30-INCH PISTON STROKE PRIOR TO THE NEW GREAT WESTERN TYPE SHOWN IN FIG. 12

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Webb in 1897, must be classed as distinctly abnormal. She was emphatically an experiment whose outcome was her rebuilding as a compound. Mr. D. Drummond's four-cylinder non-compound, No. 720, was also abnormal; but after several years of trial she has become so far normal as to be multiplied six-fold. Mr. J. Manson's No. 11,—also four-cylinder non-compound,—on the Glasgow & South-Western, still remains abnormal, but rumour hints at multiplication. Lastly among that type, Mr. Ivatt has introduced a new specimen on the Great Northern in the shape of a ten-wheeled engine of the "Atlantic" order, with leading bogie, four-coupled 6-foot 6-inch drivers, and a pair of trailing wheels. She, too, is still in the experimental stage.

It would hardly be accurate to class the Worsdell von Borries compounds as of an abnormal type. When Mr. T. W. Worsdell brought out No. 230 in 1884, undoubtedly she was so; but ten more were speedily added on the Great Eastern, and no doubt many others would have followed on that railway had not their designer migrated to the North-Eastern, where he introduced a considerable number of the type which, although it is steadily dying out in Britain, has been largely multiplied abroad. It, too, must be admitted to have taken its place among the world's normal locomotives, like the compounds of Mr. Webb in England, of M. de Glehn in France, Switzerland, and Germany, and of Mr. Vauclain in America. So, too, the "Atlantic," or ten-wheeled, type, whose pioneer was Mr. Ivatt's No. 990, on the Great Northern, has "come to stay" in England and France, as it long has done in America. Although in Britain it is represented by only twelve enginess on the Great Northern and about sixty on the Lancashire & Yorkshire, its manifest usefulness and large capability has firmly established it as one of our most important locomotive types, and its extension to all or most of the British railways is only a question of time.

The same, apparently, may be said of the other ten-wheeled express type, the six-coupled with leading bogie. Long in use not only in the United States, but also in Canada, Australia, and New Zealand, as well as latterly in France, as a valuable machine for the haulage of heavy expresses on steep gradients, it has now become one of the normal British classes. Mr. W. Worsdell's No. 2001, with six-coupled, 6-foot wheels and cylinders 20 × 26, was never a solitary freak or curiosity. It came out as one of a batch of ten, which was quickly followed by a second batch of five, identical save in having 6-foot 8-inch coupled wheels and a weight of sixty-seven tons, then unparalleled in British practice. And Mr. Peter Drummond came quickly after with his similar Highland engines, which have smaller wheels and cylinders, but larger boilers than the North-Eastern engines. Mr. J. G. Robinson promptly placed several of a similar order on the Great Central, and finally either Mr. W. Dean, the late Locomotive Superintendent of the Great Western, or Mr. J. G. Churchward, his present able successor,—the advent of the new locomotive was so closely coincident with Mr. Dean's retirement that I cannot pretend to say whether he or his successor ought to be credited with its merit,—has brought out "No. 100," which is of the same type as the latest North-Easterns just referred to, but which, with wheels of identical size, viz., 6 feet 8 inches, has cylinders 2 inches less in diameter, and a piston stroke 4 inches longer, with a boiler larger than that of any British express engine yet constructed. It has one absolutely abnormal feature, viz., its piston stroke, 30 inches in length; but if, as is reported, more are to be built, this peculiarity will soon cease to be a peculiarity, on the Great Western, at any rate. Still, the feature represents unquestionably a marked divergence from normal British practice.

One variant of the ten-wheeled six-coupled type is specially noteworthy. I refer to the new engines Nos. 55-59, designed and built by Mr. J. P. M'Intosh for the steeply-graded Oban branch of the Caledonian line, which have six-coupled wheels only 5 feet in diameter,

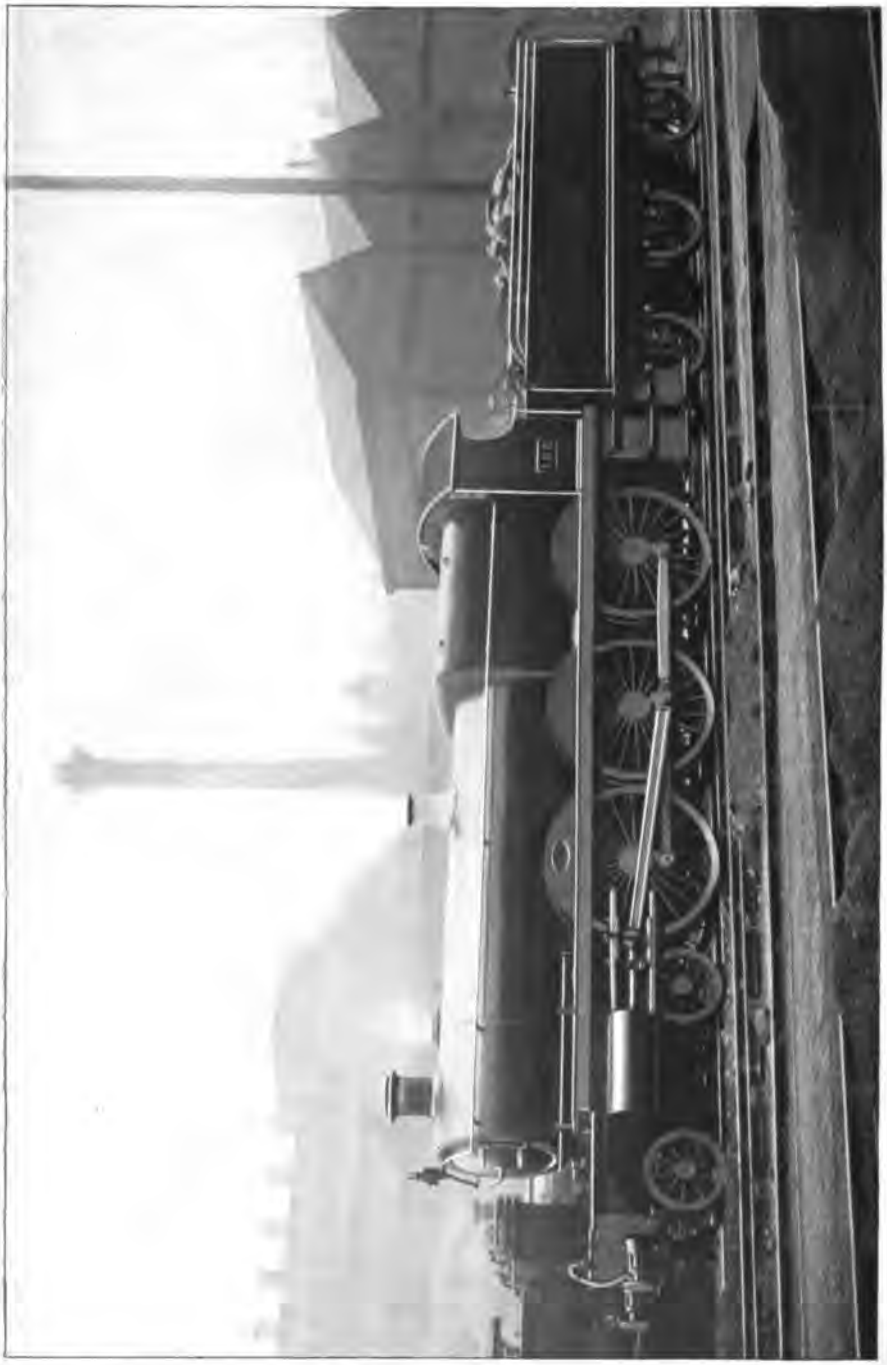


FIG. 12.—THE NEWEST GREAT WESTERN EXPRESS ENGINE; 6 FT. 8 IN. COUPLED WHEELS; 18-INCH CYLINDERS AND 30-INCH PISTON STROKE.

PHOTO BY F. MOORE

all placed close together, and a leading four-wheeled bogie, the front pair of coupled wheels being the drivers, and the cylinders being inside the frames. This is, as yet, a wholly abnormal method, and it has yet to be seen whether it will come into common use. The engines appear entirely successful, but it has been doubted by some whether the type would be suitable for fast main-line duty, owing to the difficulty of employing wheels large enough for that class of service, yet small enough to have the boiler and fire-box above them and to admit the connecting-rods of inside cylinders. I am inclined to anticipate that it will, by degrees, establish itself.

The old-fashioned notion that express driving wheels must needs be large, which, as I remarked earlier in this article, was so widely prevalent in the childhood of railways, has now greatly weakened as a result of practical experience, especially on the American and European continents. Driving wheels only 5 feet 6 inches in diameter have proved themselves to have capabilities that in former days were gravely doubted and it has become a matter of serious question whether such advantages as may accrue from the use of large wheels are not heavily discounted by the consequent loss of tractive power.

In connection with this it may be worth while to glance, in passing, at two locomotive types, each quite abnormal in its way, which more strictly belong to an early portion of this article, yet which could not well be made then to fit into the general scheme of arrangement. They are those with, respectively, the largest and the smallest four-coupled wheels ever employed in British express work. The former are, of course, those two engines built in 1896 by Mr. Wilson Worsdell for the North-Eastern Railway's Anglo-Scottish express duty, Nos. 1869 and 1870, which have driving wheels 7 feet 7¼ inches in diameter. They have not been multiplied, and remain abnormal. Probably they always will remain so. They have latterly been employed on very suitable duty,—the running of specially fast-timed light trains,—but this is done equally well by engines with smaller wheels, which, on the other hand, can haul trains that the big-wheelers could not "look at." I do not expect to see any more locomotives built with 7-foot 7¼-inch coupled wheels. I do not quite know why any should ever have been built. I think it was a mistake.

At the other extreme end of the driving-wheel dimensions list come the "Stella" class engines on the Great Western, No. 3205, 2502, etc., which were built to work the Great Western express traffic over the excessively steep gradients of South Devon and Cornwall, and did it very fairly, too, with four-coupled 5-foot wheels, and cylinders 17 inches × 26 inches, but no leading bogie. Possibly this lack was their weak point on those frequent curves. At any rate, they were virtually condemned for express duty, and having long been superseded by bogie engines with 5-foot 8-inch coupled wheels, have been relegated to stopping-trains, which they seem to work quite satisfactorily.

With regard to goods engines and tank engines, there has never been the same tendency to indulge in abnormalities or "freaks" as has been shown in the case of express locomotives. Mr. Webb's first eight-coupled goods engine was only "one among so many," and now has scores of fellows, differentiated merely in details. But one of these differs from the rest in having dimensions so vast as to be without parallel in Britain. Mr. J. F. M'Intosh's mineral engine of the "600" class, with its eight-coupled, 4-foot 6-inch wheels, its huge boiler with 2500 square feet of heating surface, and its four safety valves, is as yet unique as a class. But its unusualness consists mainly in its dimensions.

Mr. M'Intosh, as a rule, adheres as far as possible to the normal in general design. His justly celebrated "Dunalastairs,"—in their three slightly different sizes,—possessed few absolutely new features. It was the excellence of their general design and mainly the largeness of their boilers which won them their fame, and secured them the rare com-

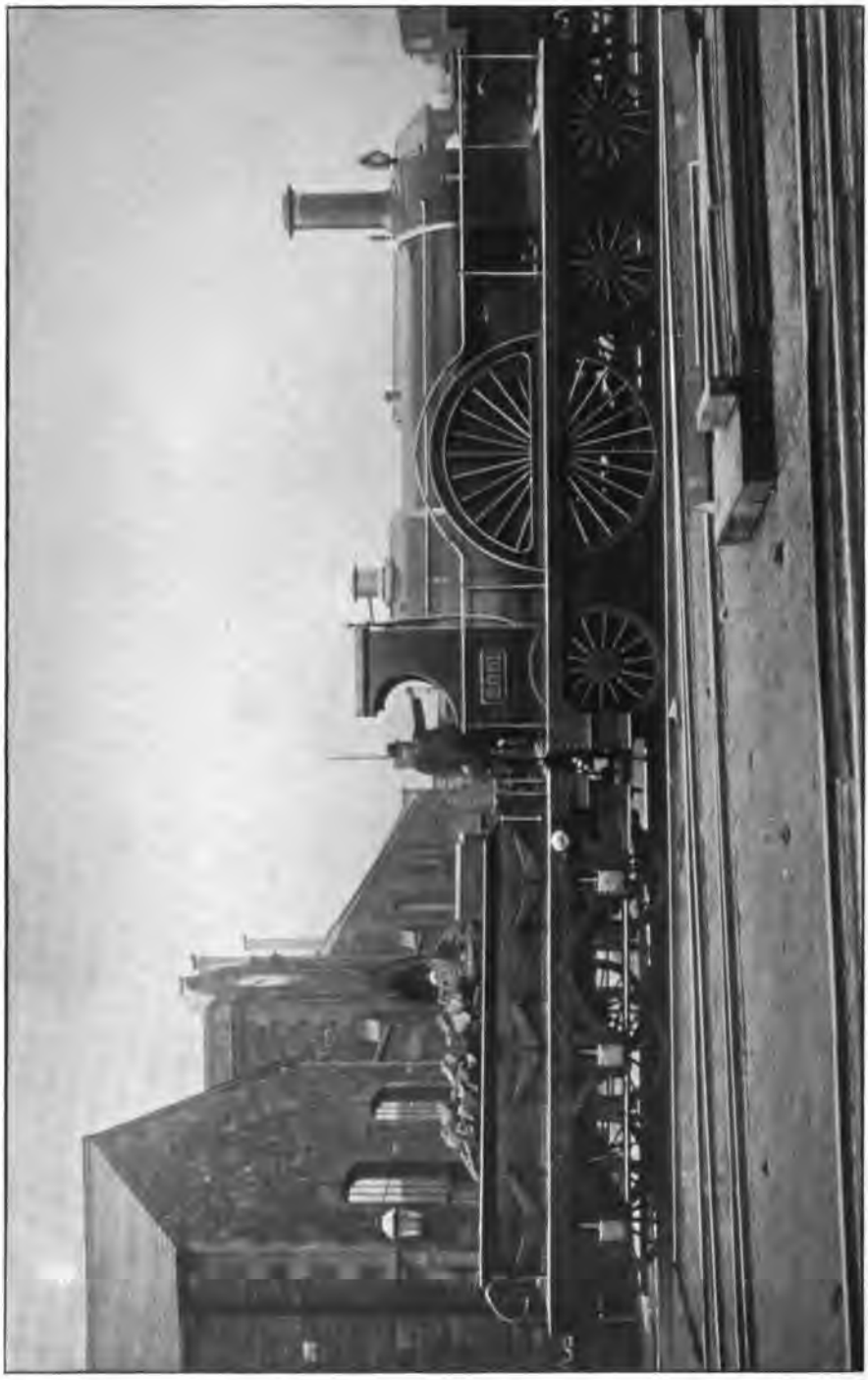


FIG. 13.—A BRISTOL & EXETER EXPRESS TANK ENGINE. REBUILT AS A TENDER ENGINE BY THE GREAT WESTERN RAILWAY. THE ENGINE HAS 8-FOOT DRIVING WHEELS

pliment of adoption also as the standard type for the State Railways of Belgium. Mr. M'Intosh does not aim at building "freaks." He prefers efficient trustworthiness. This merit attaches to many other British four-coupled engines, such, for instance, as the Great Western "Atbara" and "Camel" classes; the Great Eastern "Claud Hamiltons"; the Great Northern "990" and "1321" classes; the Midland "Belpaires"; the North-Eastern "2011" set; and the Lancashire & Yorkshire "1400's," merely to mention a few prominent cases, to which others might well be added.

But while there is an unquestionable advantage in persistence in types which practical experience has proved to be sound and serviceable, with simple enlargement of the dimensions as the growing demands of traffic may necessitate, it will be manifest, through this review of the most important departures from the normal in the case of British locomotive engineering, that these departures do, in many cases, lead to important results. Sometimes the outcome has been to evolve a new and useful type of the normal out of an experiment with the abnormal.

In other instances a perhaps equally beneficial result has accrued in the shape of negative demonstration, viz., in the proof that novelty is not always superiority, and that the method at the time in possession need not be too readily abandoned for the sake of reforms whose sole merit may prove in practice to be merely their newness.

The subject of the article is so large that I have found it impossible to deal with more than its British phase in a single paper. I must, therefore, leave its foreign side, which is also very interesting, to be treated on a future occasion.

BUSINESS TRAINING FOR THE ENGINEER

By Alex. C. Humphreys, M. E., M. Inst. C. E., President of Stevens Institute of Technology

SELF-EVIDENT should be the truth of the proposition that the engineer ought to be a man of business, or at least informed of, and prepared to conform to, business conditions and business methods. When this proposition is squarely laid before them it is self-evident to the majority of successful engineers and men of business. Business men, bankers, and manufacturers not infrequently refuse their confidence to engineers and experts as a class because, under trial, some individuals have demonstrated their incapacity to meet business conditions; from the standpoint of the man of business their reports, advice, conclusions have required interpretation and readjustment or amendment.

The man, so far somewhat exceptional, who is able to bring to the service of his clients or associates a sound technical training and the ability to meet business conditions, proves by his comparative success the material value of this dual capacity. For the sake of the profession and the country at large it is important that this broader capacity should no longer be exceptional.

To this end the professional educator and the engineer-student must better recognise the conditions to be met in practice. A general and definite demand on the part of the business world for engineers of such broader capacity would ensure the necessary reform in the separate schools of engineering and the university departments of applied science. All that is possible should be done in the technical schools to harmonise theory and practice.

Great Britain recognises this interdependence, and her foremost men are finding in the lack of sufficient technical training the explanation of Britain's loss of commercial supremacy. Professor

John Perry, for example, concluded a notable address recently delivered before the engineering section of the British Association for the Advancement of Science in these words:—

"When men can hardly take a step without seeing steam engines and electro-motors and telegraphs and telephones and steamships, with drainage and waterworks, with railways and electric tramways and motor-cars, when every shop window is filled with the products of engineering enterprise, it is getting rather difficult for people to have any belief in evil spirits and witchcraft. All the heart-breaking preaching of enthusiasts in education would produce very little effect upon an old society like that of England if it were not for the engineer."

From a recent article by Sir Philip Magnus on the present industrial importance of technical education, I give two short quotations:—

"In the report of the special committee of the London County Council, to which I have already referred, it is, I think, conclusively shown that of late years we have lost other branches of trade than those above named, and that this loss is largely due to the superior educational equipment of our neighbours."

"The successful engineer must be, of necessity, a man of business."

After graduation the young engineer will be influenced by commercial conditions, and perhaps by his own natural bent, to become a specialist. To-day the field of engineering is so wide and the requirements are so exacting that no man can expect to excel unless he confines himself within certain rather narrow limits. But no matter to what part of the field he confines his efforts he will surely find himself limited and bound, more or less, by commercial conditions.

From this it may be argued that the engineer should not aim to be also the commercial manager; as a specialist he should confine himself to the engineering branch of his business. To this it may be replied that whatever special branch of industry is adopted, the engineer must understand and practice in harmony with the commercial conditions of that specialty. There may be a further specialisation between the engineering and the commercial management, but the engineer should have at least a knowledge of the general fundamentals of business practice and also a knowledge of the special limitations attaching to the particular business pursued.

As in schools of engineering we cannot expect to instruct the students in all the specialisations of engineering science and practice, so with instruction in business methods we can expect to give only a broad training in fundamentals upon which the student can safely and expeditiously build when the need for specialisation is encountered.

If it be admitted that the engineer-student should receive some instruction in business methods before graduation, it then remains to be determined what can be added in this connection to a course already crowded almost to the limit. Perhaps the matter of first importance is accounting. We cannot expect to train the students to be expert bookkeepers, nor is it necessary to do so; but we can expect to give them what is of more value and what many bookkeepers do not possess,—a sound knowledge of the principles of double-entry bookkeeping. This knowledge engineers need to enable them to exercise a close, intelligent, and independent supervision of manufacturing cost.

The students should be taught to carefully and conscientiously discriminate between the charges to capital or revenue, and they should be warned of the ease with which errors can be made in this connection and the disastrous consequences likely to follow their commission. They should also be shown the necessity for making adequate provision for depreciation of plant, the scheme to be based upon an exhaustive analysis of local conditions and not upon the blind acceptance of arbitrary rules formulated by accountants. They should be shown that books can be so kept, either through ignorance or design, as to hide the facts and to present a warrant for the payment of dividends

unearned. They should be shown that all this, and much more, they will need if they are to be competent as managers or reliable as advisors in connection with the purchase of properties.

They can also be shown that often, when called in to pronounce on the value of some new apparatus or process where these have already been under commercial test, the technical investigation may well be supplemented by a competent examination of the books of account; and that here the man who is only an engineer or only an accountant will probably be found incapable of conducting such an examination. In such a course might also well be included enough instruction in the science of statistics to warn the student against the danger of drawing conclusions from insufficient or inconsistent data.

In connection with the work in this and other departments the effort should be made to bring the students to a keener appreciation of the value of a working command of English. They should be shown that it is not enough that they possess the knowledge, but they must have the ability to convey to others, and especially to their clients, in language concise and free from ambiguity, the results of their professional or administrative work.

Unquestionably there is a crying need for more efficient work in the teaching of English in the schools of technology, and perhaps this statement may fairly be extended to include some of the colleges and universities. Reform in this direction is most difficult of accomplishment. The work performed is too often of a perfunctory character, whereas it should be characterised by enthusiasm and originality. The time available is limited, and, therefore, the first care should be to give such a t aining in English as will be most efficient to meet the requirements of professional practice.

This leads naturally to another feature which may well be included in the department of business methods,—instruction in the law of contracts. We cannot expect to give engineer-students a working knowledge of the law of contracts, but we may very reasonably expect to impress them with the dangers to be encountered and the necessity of knowing when it is advisable to seek thoroughly competent legal advice. Some advice in this line can also, to advantage, be included in the lectures on engineering practice.

At Stevens Institute of Technology a course in business methods was started in 1897, though it was not until two years later that the work was put upon a firm basis. At first a number of engineers and bankers gave a series of lectures to the senior class, to point out by examples from their own professional and business experiences the necessity for the engineer to recognise that his work must be in accord with commercial practice. Two years later ten lectures on accounting were delivered to the junior class; but as this work was left optional, the students derived little benefit from it. For the last three years the course has included twenty lectures and recitations, followed by regular examinations. It is believed that this course has been of real value, and could have been made of far more value if the students in the first few lectures could have been brought to believe that this is a subject which properly belongs in a course in engineering.

Now this part of the curriculum has been again carried forward to the senior year. It is hoped and believed that from now on this feature of the curriculum will be of much greater value to the students because the first few lectures will be delivered by successful engineers and business men who have in their work demonstrated the necessity, or at least the advisability, of such training. It is believed that the students will be ready to accept such testimony and act upon it where they would not do so if the advice were offered by professional educators or accountants.

As it is important that the first year's class should be promptly impressed with the practical necessity for such a knowledge of English as has been already spoken of, a few talks will be given to the entering classes to bring them into a more sympathetic and receptive mood

toward this and all other non-technical studies included in the curriculum.

Generally the entering class in their wisdom are ready to promptly denounce as useless or out of place these non-technical studies; thus the sympathetic co-operation of the students, which is such an important element in the efficient teaching required in a full course of study, is not obtained, and the foundation is laid for many regrets to be experienced in the years after graduation.

THE MODERN POWER PROBLEM

I.—ELECTRIC AND COMPRESSED AIR POWER

By Professor John Joseph Flather

Professor Flather's review of modern tendencies in the utilisation of power is a comprehensive summing-up of what has been accomplished in this field by the best effort of the times. It takes up, in turn, electric, compressed air, and hydraulic transmissions, and forecasts a promising future for the internal combustion engine and the steam turbine. Originally Professor Flather's remarks were delivered before the Engineering and Mechanical Science Section of the Association for the Advancement of Science, but were somewhat condensed and revised specially for publication here with selected illustrations of examples of modern shop equipment.—THE EDITOR.

THE ELECTRIC DRIVE

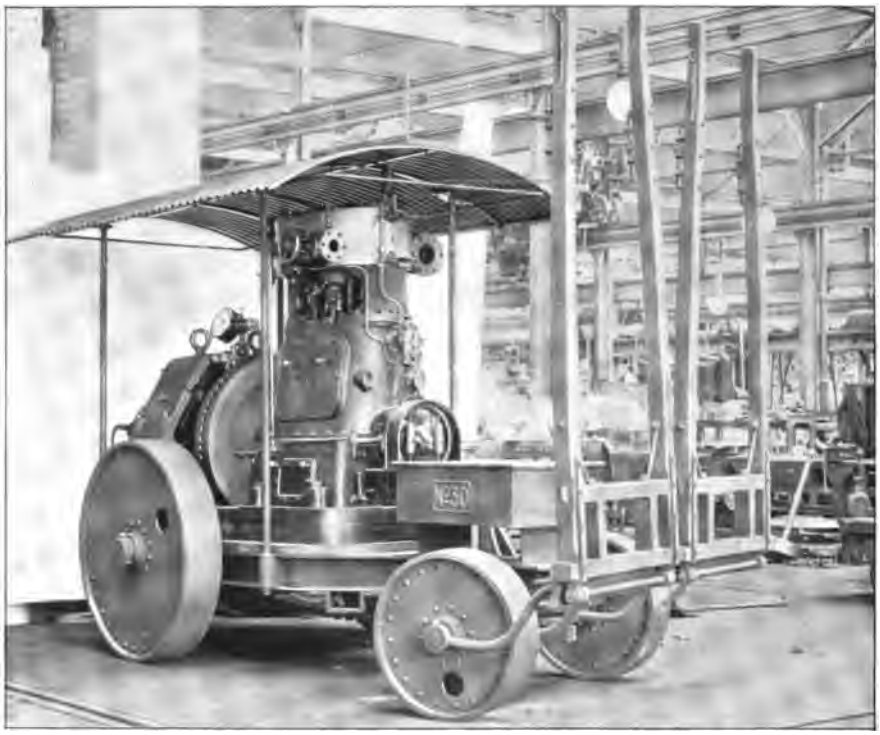
SPECIALISATION in the manufacture of machine tools and labour-saving devices has followed closely the segregation of processes in other lines of industry, and thus there has been created a multitude of special machines, each designed to perform some single, and often very simple, operation.

Among other significant features the present tendency in the development and use of this class of machinery is marked by the adaptation of compressed air and the application of electric power to machine driving. In the use of compressed air the facility of adaptation to various requirements which are in many cases additional to the supply of motive power is a valuable feature peculiar to this system, and one which is susceptible of extension along many lines.

The labour cost in most machine shops and other works is so much greater than the cost of power that any expedient by which the labour cost may be appreciably reduced is justified, even though the efficiency of the agent itself be low. Whenever new methods or agencies cause an increased production with a given outlay for labour we shall find these methods superseding the old, even though the cost of the power required be greater than before. The saving of power is a consideration secondary to the advantages and economical output obtained by its use. While economy in the use of power should, therefore, be secondary to increased output, careful attention to details will often greatly reduce the useless waste of power.

Engineers have recognised for some time past that a very large percentage of loss is due to shaft friction, which, in railway and other shops, where the buildings are more or less scattered, may be as great as 75 per cent. of the total power used. In two cases known to the writer these losses are 80 and 93 per cent., respectively. In the ordinary machine shop this loss will probably average from 40 to 50 per cent. No matter how well a long line of shafting may have been erected, it soon loses its alignment, and the power necessary to rotate it is increased.

In machine shops with a line of main shafting running down the centre of a room, connected by short belts with innumerable countershafts on either side, and often also connected to one or more auxiliary shafts which drive other coun-



A PORTABLE ELECTRIC LIGHT OUTFIT, MADE BY MESSRS. W. H. ALLEN, SON & CO., LTD., BEDFORD, ENGLAND

tershafts, we can see why the power required to drive this shafting should be so large. There is no doubt, however, that a large percentage of the power now spent in overcoming the friction of shafting in ordinary practice could be made available for useful work if much of the present cumbrous lines of shafting were removed.

Manufacturers are realising the loss of power which ensues from the present system of transmission, and we find a general tendency to introduce different methods by which a part of this loss will be obviated. Among these are the introduction of hollow and lighter shafting; higher speeds and lighter pulleys; roller bearings in shaft hangers; and the total, or partial, elimination of the shafting. Independent motors are often employed to drive sections of shafting and isolated machines, and among these we find steam and gas engines, electric motors, and compressed air and hydraulic motors, although the last have not been used for this purpose to so great an extent as the others.

Until quite recently the steam engine was the principal motor to be used, especially where the units were relatively large. An interesting example of this is noted in the sugar refinery of Claus Spreckles, in Philadelphia, in which there are ninety Westinghouse engines about the works, many of them of 75 and 100 H. P. each, others of only 5 and 10 H. P. A similar sub-divided power plant involving forty-two engines was erected several years ago at a large print works.

It was only a comparatively few years ago when large and economical Corliss engines were replaced at the Baldwin Locomotive Works by a great number of small, simple-expansion engines, which actually required about 15 per cent. more steam per horse-power-hour than the Corliss engines. This loss,

ELECTRICALLY DRIVEN POST DRILLS IN THE SHIPYARD OF MESSRS. YARROW & CO., LTD., POPLAR, LONDON

however, was only apparent, for by increasing the number of units and locating them at convenient centres of distribution much of the shafting and belting could be dispensed with and an actual saving was obtained. Later, these simple engines were replaced by a number of compounds, about eighteen being in service; subsequent tests on these showed a saving of 30 per cent. over that obtained by the use of the simple engines. More recently, however, the electric motor has superseded the steam engine for this work.

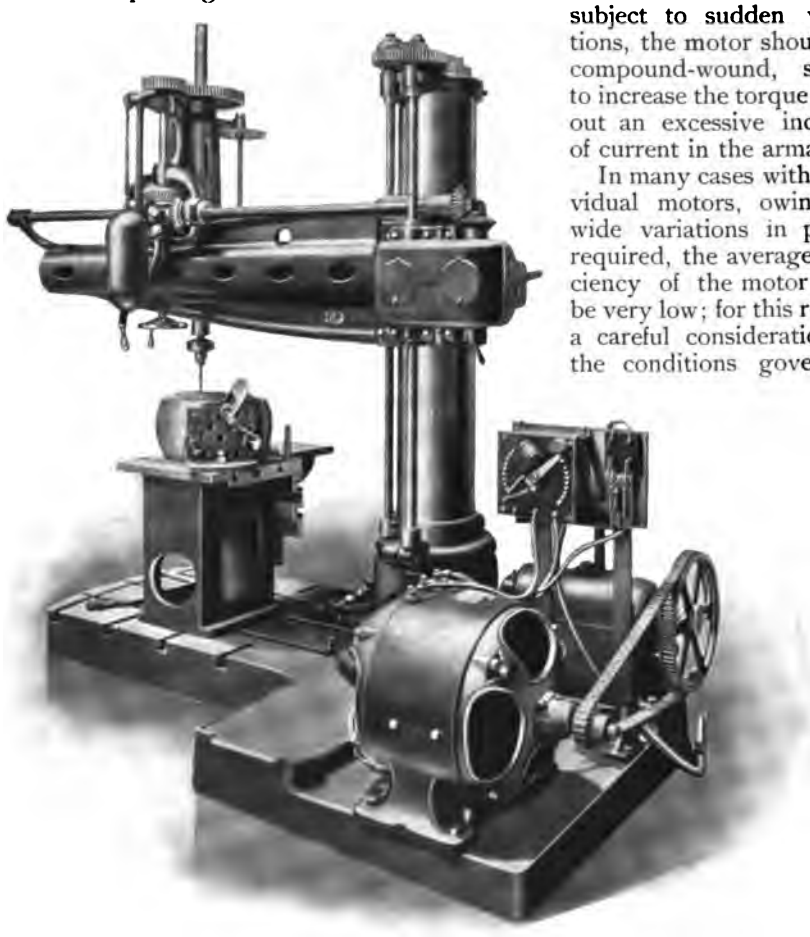
The introduction of the electric motor in machine shops and factories was at first looked upon with disfavour, and was opposed by many manufacturers; but the innovation obtained a foothold, and advantages which were at first unforeseen were found to attend its use, so that now it is being very generally adopted for a wide variety of work.

A considerable difference of opinion exists as to whether individual motors should be used with each machine, or whether a number of machines should be arranged in a group and driven from a short line-shaft. There are well-defined conditions to which each system is best adapted, but there are wide limits between which there appears to be no general rule, and we find both methods occupying the same field.

For isolated machines and for heavy machines that may be in occasional use the individual motor is particularly well adapted, as it consumes power only when in operation. It is, however, necessary that each motor thus connected shall be capable of supplying sufficient power to operate its machine under the heaviest, as well as the lightest loads. In certain cases, moreover, the load is liable to very great irregularity, as, for instance, in metal-working planers, in which the resistance offered by the machine at the moment of reversal of the platen is far higher than at other times, and may be so great as to endanger the armature of the motor. Under these conditions it is necessary

to use a motor of much larger capacity than the average load would indicate.

Fortunately, with electric motors the rated capacity is usually less than the safe maximum load, which is determined either by the heating of the conductors, tending to break down the insulation, or by excessive sparking at the brushes.



A RADIAL DRILL, MADE BY THE BICKFORD DRILL & TOOL CO., CINCINNATI, OHIO, U. S. A., DRIVEN BY A GENERAL ELECTRIC COMPANY MOTOR THROUGH A RENOLD CHAIN

For momentary overloads relatively large currents may pass through the coils without injury to the insulation, since the temperature effect is cumulative and requires time for its operation. However, for continuous periods of considerable length, it is usually unsafe to operate the motor much above its rated output.

Ordinarily in machine-driving the motor is shunt-wound, and the current through the field coils is constant under all conditions of load; but to obtain the best results with this class of machinery, in which the load is intermittent and subject to sudden variations, the motor should be compound-wound, so as to increase the torque without an excessive increase of current in the armature.

In many cases with individual motors, owing to wide variations in power required, the average efficiency of the motor may be very low; for this reason a careful consideration of the conditions governing each case indicates that for ordinary machine-driving, especially with small machines, short lengths of light shafting may be frequently employed to good advantage, and the various machines, arranged in groups, may be driven from one motor. By this

A PUNCHING AND SHEARING MACHINE EQUIPPED WITH ELECTRIC DRIVING, BY MESSRS. ERNEST SCOTT & MOUNTAIN, LTD., NEWCASTLE-ON-TYNE, ENGLAND

method fewer motors are required, and each may be so proportioned to the average load that it may run most of the time at its maximum efficiency.

When short lengths of shafting are employed, the alignment of any section is very little affected by local settling of beams or columns, and since a relatively small amount of power is transmitted by each section, the shaft may be reduced in size, thus decreasing the friction loss. Moreover, with this arrangement, as also with the independent motor, the machinery may often be placed to better advantage in order to suit a given process of manufacture; shafts may be placed at any angle, without the usual complicated and often unsatisfactory devices, and setting-up room may be provided in any suitable location as required without carrying long lines of shafting through space. This is an important consideration, for not only is the running expense thus reduced, but the clear

head-room so obtained, free from shafting, belts, ropes, pulleys, and other transmitting devices, can be more easily utilised for hoists and cranes, which have so largely come to be recognised as essential to economical manufacture.

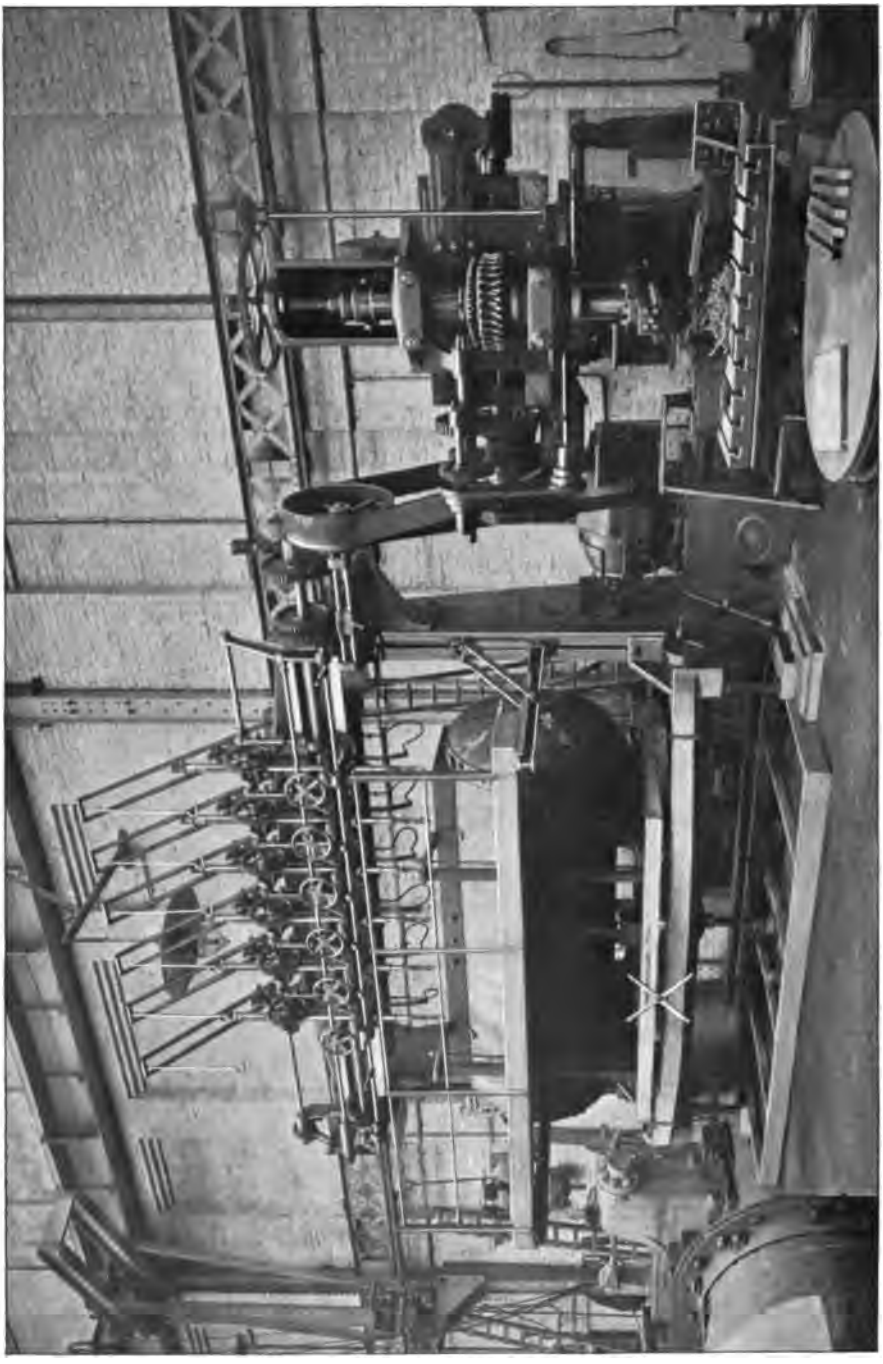
In arranging such a system of power distribution, the average power required to drive is of as much importance as the maximum, for in a properly arranged group-system the motor capacity need not be the equivalent of the total maximum power required to operate the several machines in the group, but may be taken at some value less than the total, depending upon the number of the machines and the average period of operation. On the other hand, as already shown, the motor capacity of independently driven machines must not only equal the maximum power required to drive the machine at full load, but it must be capable of exerting a greatly increased momentary torque. In any case, large units should be avoided, for the multiplication of machines driven from one motor entails additional shafting, countershafts, and belting which may readily cause the transmission losses to be greater than those obtained with engines and shafting alone, besides frustrating some of the principal objects of this method of transmission.

As far as the efficiency of transmission is concerned, it is doubtful whether in a large number of cases motor-driving *per se* is any more efficient than well-arranged engines and shafting. As already pointed out, the principal thing to be kept in mind is a desired increase in efficiency of the shop plant in turning out product with a reduction in the time and labour items, without especial reference to the fuel items involved in the power production.

On account of the sub-division of power which results from the use of many motors there is less liability of interruption to manufacture, and, in case of overtime, it is not necessary to operate the whole works, with the usual heavy load of transmitting machinery.

Another advantage is the adaptability to changes and extension. New motors may always be added without affecting any already in operation, and the ease

AN ELECTRICALLY DRIVEN, PORTABLE, DOUBLE-END SAND SIFTER, MADE BY MESSRS. GOULD & EBERHARDT, NEWARK, N. J., U S A.



A 6-SPINDLE DRILLING MACHINE FOR BOILER WORK AT THE WORKS OF MESSRS. YARROW & CO., LTD., LONDON, ENGLAND. BUILT BY MESSRS. G. BUCKTON & CO., LTD., LEEDS. THE SPINDLES CAN BE ADJUSTED, OR FED AUTOMATICALLY, INDEPENDENTLY OR SIMULTANEOUSLY. THE MACHINE ADMITS WORK MEASURING 14 FT. 6 IN. BETWEEN THE UPRIGHTS, AND 7 FT. 6 IN. HIGH ON THE TABLE UNDER THE SPINDLE END

with which this system lends itself to varying the speed of different unit groups is a very potent factor in its favour.

One serious obstacle to the use of connected motors with machine tools is the difficulty of obtaining speed variation which is so necessary with a large proportion of the machines in common use. A certain amount of variation can be obtained by using a single-voltage system with shunt-field regulation; but the variation in this case is very limited, though it may be increased by using a double commutator if space will permit.

The three-wire, 220-volt system offers many advantages both for power and lighting systems, and is very frequently employed. Variations of speed may be obtained with this system by using a combination of field regulation with either voltage, and, in rarer cases, the use of a double-commutator motor.

A method which has been used recently with considerable satisfaction involves the use of a three-wire generator, with collector rings connected to an armature winding, similar to that of a two-phase rotary converter. Balancing coils are used, and the middle points of these are connected to the third wire, which is thus maintained at a voltage half way between the outer wires. This system is simple and economical, and possesses all the advantages of the ordinary three-wire method, which permits similar variations in speed by field regulation with either voltage; and if still wider ranges are desired, a double-commutator motor may be used.

In other recent installations the four-wire, multiple-voltage system is used, which permits of very wide variations of speed in the operation of the tool. This system gives excellent results, and removes one of the objections urged against direct-connected, motor-driven tools, namely, that such machines are not sufficiently flexible in regard to speed variation, and that such variation can be obtained only by throwing in resistances which cut down the efficiency of the motor, or by varying the strength of field which reduces the torque.

The multiple-voltage system, however, has some serious disadvantages. It cannot usually be operated from an outside source of power without rotary transformers; the generating sets and switchboard are complicated, and the total cost of installation is expensive; yet with these drawbacks the system is growing in favour, as it has manifest advantages which outweigh the objections.

AN ELECTRIC MOTOR DRIVING A CIRCULAR SAW DIRECT, THE WHOLE MOUNTED ON THE TOOL REST OF A LATHE. MADE BY MESSRS. MATHER & PLATT, LTD., GLOUCESTER, ENGLAND

The storage battery has been used to some extent to obtain multiple control, and is suggestive of interesting possibilities; but in its present form it is not altogether desirable for machine tools.

In many of the larger sizes of certain metal-cutting machines it is probable that marked changes will be produced in the immediate future, and the indica-

ELECTRICALLY DRIVEN SHEARING MACHINE IN THE WORKS OF MESSRS. YARROW & CO., LTD., LONDON, BUILT BY MESSRS. FRANCIS BERRY & SONS, SOWERBY BRIDGE, ENGLAND

tions are that direct-connected motors with wide variations of speed and power will be incorporated in the new designs.

The recent improvements in the manufacture of certain grades of tool steel have shown indisputably that the present designs of machine tools are not sufficiently heavy to stand up to the work in order to obtain the economy of operation which results from the use of such steels. Higher speeds, heavier cuts, and greater feeds may be obtained if the machines will stand the strain; but in most cases the capacity of the machine is not commensurate with the ability of the tool to remove metal. With cutting speeds of 100 to 200 feet per minute, it is evident that the power requirements will be much greater than for the ordinary machines of to-day, which have a cutting speed of from 10 to 30 feet per minute. As an illustration of what can be done with these new tool steels, the writer was recently shown some steel locomotive driving wheels which had been turned up in two hours and forty minutes, whereas the regular time formerly required was not less than eight hours. In this case even better results could have been obtained, but the belts would not carry the load. Here, then, we find an interesting field

for the direct-connected motor with ample power and speed variation for any work which it may be called upon to perform.

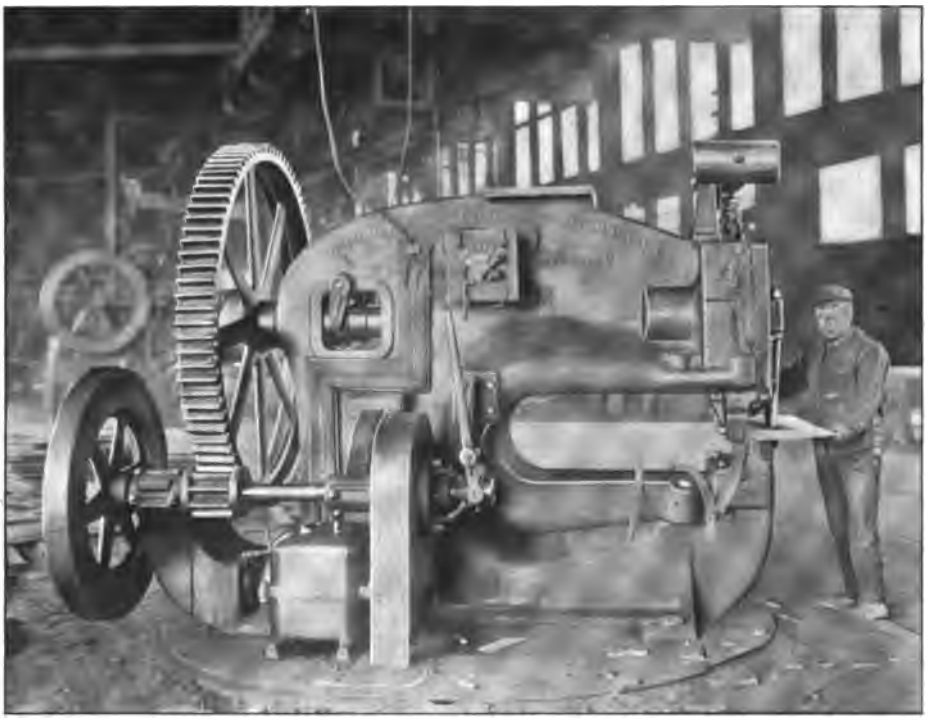
While the preference is easily given to continuous-current motors for the purposes of machine driving, yet we find alternating-current motors used to a considerable extent, the proportion of motors in service being about 1 to 5 in favour of the continuous-current motor. Both synchronous and induction motors are employed, but the advantages possessed by the latter cause this type to be preferred, although in long-distance transmissions both types should be used in order to obtain satisfactory regulation.

The induction motor can readily be worked at variable speeds, regulation being accomplished in three different ways:—First, by rheostatic control, which is decidedly the cheapest and easiest method to manipulate; second, by varying the impressed voltage, which, however, necessitates the use of a transformer or compensator with variable ratio, and this is very inefficient at the lower speeds and can be used only under certain conditions; and third, by altering the number of poles, which is mechanically very complicated; but where the speed variation is only one-half or one-quarter it may be used efficiently.

One serious disadvantage met with in all induction motors is the lag produced by the self-excitation and self-induction and its reaction on the circuit. This lag is particularly unsatisfactory with intermittent service, such as machine driving, where the motors have to run under light and variable loads; in such cases the power factor is probably not over 60 or 70 per cent.

COMPRESSED AIR

Reference has been made to the use of compressed air and its facility of



AN ELECTRICALLY DRIVEN PUNCH IN THE SHOPS OF THE HARLAN & HOLLINGSWORTH COMPANY, OF WILMINGTON, DELAWARE, U. S. A., MADE BY BY THE HILLES & JONES COMPANY OF THE SAME PLACE

A COMPRESSED AIR LOCOMOTIVE IN LUMBER YARD SERVICE, MADE BY THE H. K. PORTER CO., PITTSBURGH

adaptation to various requirements; but it is evident, from an inspection of some of the devices in use, that enthusiasm for new methods, rather than good judgment, has prevailed in many of its applications. For some years compressed air was used only in mines, where it produced marked economies. Later, it was introduced into manufacturing lines, and to-day its use in railway and other machine shops, boiler shops, foundries, and bridge works is being widely extended.

The air is used to operate riveting machines, punches, stay-bolt breakers, stay-bolt cutters, rotary tapping and drilling machines, fine rollers, rotary grinders, rotary saws, pneumatic hammers, chisels, and calking tools, flue welders, boring and valve-facing machines, rail saws, machines for revolving driving wheels for setting valves, pneumatic painting and whitewashing machines, dusters for car seats, and the operation of switching engines about the yard. It is also used in the foundry for pressing and ramming moulds, and for cleaning castings by the sand blast; but its greatest field of usefulness is its application to hoisting and lifting operations in and about a works.

New applications of compressed air are constantly being made, and each new use suggests another. This has a tendency to increase the number of applications which are intended to be labour-saving devices, but in many cases the work could be done just as well and much more cheaply by hand.

A case in point is seen in an apparatus which was at one time in use on one of the more prominent railways. It was a sort of portable crane hoist which could be fastened to the smokestack of a locomotive whereby one man could lift off the steam chest casings. The hoisting apparatus weighed about twice as much as the steam chest and took three men to put it up. When piece-work was adopted two men easily lifted off the steam chest, and this "time and labour-saving device" was relegated to the scrap heap.

While compressed air has been used, to some extent, for inducing draught in forge fires, it is unquestionably a very expensive agent for such work. Tests have shown that it costs twenty-five times as much to produce blast in that way as it would with a fan.

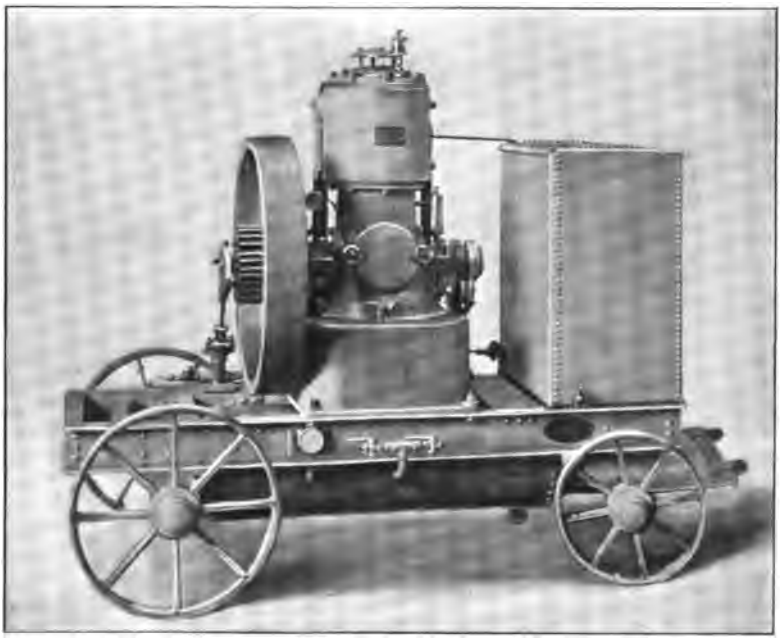
The success and economy which have attended the use of compressed air in so many lines of work have led to its adoption in fields which are much better cov-

ered by electrically operated machines. While compressed air has been used very satisfactorily under certain conditions to operate pumps and engines, printing presses, individual motors for lathes, planers, slotters, dynamos and other work, it does not follow that it is always an economical agent for these various uses, or that other methods could not be used even more satisfactorily in the majority of cases.

It has been proposed to use individual air motors in machine shops and do away with all line shafting, except possibly for some of the heavier machinery. This use of compressed air seems entirely outside the pale of its legitimate field. General experience thus far indicates that rotary air motors are not at all economical, and generally are not as satisfactory as electric motors. Exceptions are to be found in the small portable motors for drilling and similar operations to which electricity is not well adapted. The saving obtained by the use of such portable air drills, as compared with a hand ratchet drill, is very marked.

Although these tools are very successful, they are still rotary motors, not exempt from some of the objectionable features which seem to be inseparable from them. It is not surprising, therefore, to find a tendency to employ reciprocating pistons and cranks in these portable machines, and there are such tools weighing only forty pounds, capable of drilling up to 2½ inches diameter.

In most cases no attempt has been made to use the air efficiently; its great convenience and the economy produced by its displacement of hand labour have until recently been accepted as sufficient, and greater economies have not been sought.



A PORTABLE AIR COMPRESSOR OUTFIT. MADE BY MESSRS. LACY-HULBERT & CO., LONDON
THE ELECTRIC MOTOR FOR DRIVING THE COMPRESSOR IS NOT SHOWN HERE

In the matter of compression we still occasionally find very inefficient pumps in use, but manufacturers generally have learned that it pays to use high-grade, economical compressors. The greatest loss is that in the air motor itself. In a large number of cases it is impracticable,

A ROTARY COMPRESSED AIR DRILL, MADE BY THE Q & C COMPANY, CHICAGO, U. S. A.

A PORTABLE PNEUMATIC RIVETING MACHINE, MADE BY THE BETHLEHEM FOUNDRY & MACHINE CO., SOUTH BETHLEHEM, PA., U. S. A.

or, at most, inconvenient to employ reheaters, and we find very generally that the air is used at normal temperatures for the various purposes to which it is applied.

To obtain the most satisfactory results, the air must be used expansively; but usually where the demand for power is intermittent, no attempt has been made to reheat the air, and as a result the combined efficiency of compressor and motor is quite low, varying in general from 20 to 50 per cent. While low working pressures are more efficient than high, the use of such pressures would demand larger and heavier motors and other apparatus which is undesirable. The advantages of higher pressures in reducing cost of transmission are also well recognised, and the present tendency is to use air at 100 to 150 pounds instead of the 60 or 70 pounds of a few years ago.

By reheating the air to a temperature of about 300 degrees F., which may often be accomplished at small expense, the efficiency is greatly increased; in some cases the increase has been found to be as high as 80 per cent. While the lower pressures are yet more efficient, the loss due to higher compression is not serious.

If air be used without expansion, there is a material loss in efficiency; but, on the other hand, if it be used expansively without reheating, trouble may be experienced from drop in temperature below the freezing point. With moisture present, this drop will cause the formation of ice, which may clog the passages if proper precautions are not taken to prevent it. The low temperature will not in itself cause trouble; if, therefore, the moisture which the compressed air holds in suspension be allowed to settle in a receiving tank, placed near the motor or other air apparatus, and frequently drained, trouble from this cause will be largely avoided.

While it may be impracticable to reheat the air in certain cases, yet there are many situations where a study of means to overcome the losses referred to would result in marked economies.

The greater adaptability of compressed air to various purposes causes its use to increase along with that of the electric motor, for it has a different field of usefulness, independent of power transmission; at the same time, when the requirements are properly observed in its production and use, its economy as a motive power in special cases compares favourably with that of other systems. With a better knowledge of the principles involved, we may expect much better results than have yet been attained.

The concluding portion of Professor Flather's article, to appear in the April number, will deal with hydraulic power, gas producers, and internal combustion engines.

ELECTRIC TRANSMISSION LINES

LINE WIRE MATERIALS AND HIGH VOLTAGES

By Alton D. Adams

COPPER, aluminium, iron, and bronze all are used for conductors in long-distance electric transmissions, but copper is the standard metal for the purpose. A conductor for transmission lines should combine the best electrical conductivity, great tensile strength, a high melting point, low coefficient of expansion, hardness, and great resistance to oxidation. No one of the metals named possesses all of these properties in the highest degree, and the problem is to select the material best suited to each case. Aluminium suffers very slightly by exposure to the weather; copper and bronze suffer a little more, while iron and steel wire are attacked seriously by rust.

Iron, copper and bronze are all so hard that little or no trouble has occurred from wires of these metals cutting or wearing away at the points of attachment to insulators. Aluminium, on the other hand, is so soft that swaying of the wire may, in time, cause material wear at the supports, or it may be cut by tie wires. But lines of aluminium wire have not been in use long enough to determine how much trouble is to be expected from its lack of hardness.

A small coefficient of expansion is desirable in transmission wires, because the strain on the wire itself and on its supports varies rapidly with the amount of vertical deflection of each span, becoming greater as the deflection decreases. Only a moderate amount of deflection is desirable because of the opportunity it gives for swaying of the wires. If the material used has a large coefficient of expansion the wires show too much deflection in hot and too little in cold weather. Taking the expansion of copper as unity, that of aluminium is 1.4; of bronze, 1.1; and of iron and steel, 0.7. From these figures it follows that iron and steel wires show the least variation in the amount of sag between supports, and aluminium wire shows the most.

Wrought iron melts at about 2800 degrees, steel at 2700, copper at 1929, bronze at about the same point as copper, and aluminium at 1157 degrees F. This low melting point of aluminium may prove a source of trouble by opening a line of that material where some foreign wire falls on it. This, according to a report, was illustrated at a substation on a 30,000-volt transmission line where a destructive arc was started at the switchboard. Not being able to extinguish the arc in any other way, a lineman threw an iron wire across the aluminium lines just outside of the substation, and these lines were immediately melted through by the iron wire, thus opening the circuit. The trouble may have warranted so desperate a remedy in this case; but, as a rule, it does not pay to cut a transmission line in order to get rid of a short circuit.

In the ordinary construction of transmission lines on land the tensile strength of wire is secondary in importance to its electrical conductivity, because supports can be spaced according to the strength of the conductor used. When large bodies of water must be crossed, tensile strength is a prime requirement. Thus a 142-mile line from Colgate to Oakland, in California, crosses the Straits of Carquinez in the form of four steel cables, each ⅞ inch in diameter and 4427 feet long. Steel wire was selected for this long span, probably because it can be given a greater tensile strength than that of any other metal. Annealed iron

wire has a tensile strength between 50,000 and 60,000 pounds per square inch. Steel wires vary all the way from 50,000 to more than 350,000 pounds per square inch in strength, but mild steel wire with a strength ranging from 80,000 to 100,000 pounds per square inch is readily obtained.

Soft copper shows a tensile strength between 32,000 and 36,000 pounds per square inch, and hard-drawn copper, between 45,000 and 70,000 pounds, depending on the degree of hardness. Silicon-bronze wires vary in strength from less than 60,000 to more than 100,000 pounds per square inch, and phosphor-bronze has a tensile strength of about 100,000 pounds. Bronze wires, like those of most alloys, show a much wider range of strength than those of iron or copper.

In silicon-bronze wire the electrical conductivity decreases as the tensile strength increases. The tensile strength of aluminium wire is lower than that of any other used in transmission lines, being only about 30,000 pounds per square inch. Solid aluminium wires of large size have given trouble by breaking under strains well within their nominal strength, due probably to imperfectness or twists. This trouble is now generally avoided by the use of aluminium cables.

In that most necessary property of a transmission line,—conductivity,—copper excels all other metals, except silver. Taking the conductivity of soft copper wire at 100, the conductivity of hard-drawn copper is 98; that of silicon-bronze ranges from 46 to 98; that of aluminium is 60; of phosphor-bronze, 26; of annealed iron wire, 14; and of steel wire of 100,000 pounds tensile strength per square inch, 11. Copper wire, both soft and hard, as regularly made, does not vary more than one per cent. from the standard, and aluminium and annealed iron wires also show high uniformity as to resistance. Silicon-bronze and steel wires, on the other hand, fluctuate much in electrical conductivity. For any particular transmission line the resistance is usually determined by considerations apart from the metal to be used as a conductor, so that a line of given resistance or conductivity must be constructed of that material which best conforms to the requirements as to size of wire, weight, strength, and cost.

Allowing the weight of any definite mass of copper to represent unity, the weight of an equal mass of wrought iron is 0.87; of steel, 0.89; of aluminium, 0.30; while that of bronze is very nearly equal to that of the copper. The smallest line wire that can be used for a given length and resistance is one of pure, soft copper. Next in cross sectional area come hard-drawn copper and some silicon-bronze, either of which need be only two per cent. larger than the soft copper for an equal resistance. Some other silicon-bronze wire of greater tensile strength per square inch would require a sectional area 2.17 times that of the soft copper.

Aluminium wire with 60 per cent. of the conductivity of copper requires 1.66 of its section for wires of equal resistance. As phosphor-bronze has only 26 per cent. of the conductivity of copper, the section of the bronze must be 3.84 times that of the copper wire if their lengths and resistances are to be equal. An annealed iron wire is equal in resistance to a copper wire of the same length when the iron has 7.14 times the section of the copper. Steel, with 11 per cent. of the conductivity of copper, must have 9.09 times the copper section in order that wires of the same length may have equal resistances.

It is not desirable to use a copper wire smaller than No. 4 B. & S. gauge for transmission lines, because of the lack of tensile strength in smaller sizes. When the conductivity of a copper wire smaller than No. 4 is ample, an iron wire will give the required conductivity, with a strength far greater than that of the copper. For a line of given length and conductivity of any other metal the weight compared with that of a copper line is represented by the product of the figures for relative section of the two lines and of the weight of unit mass of the metal in question compared with that of copper.

Thus, for the same conductivity the weight of a certain length of iron wire is $0.87 \times 7.14 = 6.21$ times the weight of a copper wire. For the steel wire above named the weight is $0.89 \times 9.09 = 8.09$ times that of a copper line of equal conductivity. Phosphor-bronze in a line of given length and resistance has 3.84 times the weight of soft copper. Silicon-bronze for a transmission line must weigh from 1.02 to 2.17 times as much as soft copper for a given length and conductivity. Aluminium for a line of fixed length and conductivity, will weigh $1.66 \times 0.3 = 0.5$ times as much as copper. For a line of fixed length and resistance, hard-drawn copper will weigh about two per cent. more than soft copper.

Taking the tensile strength of soft copper at 34,000 pounds per square inch; hard-drawn copper, 45,000 to 70,000; silicon-bronze, 60,000 to 100,000; phosphor-bronze, 100,000; iron, 55,000; steel, 100,000; and aluminium, at 30,000 pounds, the relative strengths of wires with equal sectional areas compared with the soft copper are, for hard-drawn copper, 1.32 to 2.06; silicon-bronze, 1.76 to 2.94; phosphor-bronze, 2.94; iron, 1.62; steel, 2.94; and for aluminium, 0.88.

Comparing wires on the basis of equal resistances for equal lengths, with soft copper again the standard, the tensile strength of each as to it, is as follows:—A hard-drawn copper line has $1.02 \times 1.32 = 1.34$ to $1.02 \times 2.06 = 2.10$ times the strength of a line of soft copper. With silicon-bronze the strength of line wire would range between $1.02 \times 1.76 = 1.79$ and $2.17 \times 2.94 = 6.38$ times that of copper. Iron would give the line a strength as to soft copper represented by $7.14 \times 1.62 = 11.56$. Steel of 100,000 pounds tensile strength per square inch will give a line $9.09 \times 2.94 = 26.70$ times as strong as it would be if composed of soft copper. With aluminium the strength of the line would be $1.66 \times 0.88 = 1.46$ times that of copper. For phosphor-bronze the figures are $3.84 \times 2.94 = 11.29$.

From the foregoing it may be shown how many times the price of soft copper per pound may be paid for each of the other metals to form a line of given length and resistance at a cost equal to that of a soft copper line. These prices per pound for the several metals relative to that of soft copper are as follows:—Taking the price of soft copper as one, the price for hard-drawn copper must be $1 \div 1.02 = 0.98$. For silicon-bronze the price may be as high as $1 \div 1.02 = 0.98$, or as low as $1 \div 2.17 = 0.46$ of the price of soft copper wire. Phosphor-bronze may have a price represented by only $1 \div 3.84 = 0.26$ that of copper. The price of iron wire should be $1 \div 6.21 = 0.16$ of that of copper, and for steel wire of the quality stated the price can only be $1 \div 8.01 = 0.12$. Aluminium wire alone may have a higher price per pound than soft copper for the same resistance and cost of line, the figure for the relative cost of this metal being $1 \div 0.5 = 2$.

From the foregoing it appears that for a line of given cost, length, and resistance, soft copper has the least cross section and tensile strength; steel, the greatest cross section, weight, tensile strength and lowest permissible price per pound; and aluminium, the least weight and highest price per pound.

RELATIVE PROPERTIES OF WIRES HAVING EQUAL LENGTHS AND RESISTANCES

Metal in Wire	Relative Cross Sections	Relative Weights	Relative Tensile Strengths	Relative Prices per Pound for Same Total Cost
Soft copper.....	1.00	1.00	1.00	1.00
Hard copper	1 02	1.04	1.34	0.98
Very hard copper.	1.02	1.02	2.10	0.98
No.1 Silicon bronze	1 02	1.02	1.79	0.98
No 2 Silicon bronze	2.17	2.17	6.38	0.46
Aluminium.....	1.66	0.50	1.46	2.00
Phosphor bronze..	3.84	3.84	11.29	0.26
Annealed iron	7.14	6.21	11.56	0.16
Mild steel.....	9 09	8.09	26.70	0.12

The relative cross sections and weights of both iron and steel wires are so great as to prevent their general use, because of the resulting labour of their erection and large cost of supports.

So far as the first cost of the wire alone is concerned, iron may be approximately equal to copper in some metal markets. The only practical place for an iron wire, however, is one where copper would be too small or not strong

enough. Steel wire finds a place, in spite of its high resistance, in those exceptional cases where a single span of several thousand feet must be made, requiring high tensile strength. In such cases it is usually better to give the steel span a greater resistance than an equal length of the main portion of the line, so as to avoid excessive size and weight of the span. Even when this is done the resistance of the steel span would be very small compared with that of a long transmission line.

Phosphor-bronze finds little use as conductors in transmission systems because of its relatively high electrical resistance. If great tensile strength is wanted, iron or steel will supply it at a fraction of the cost of phosphor-bronze. As a conductor simply phosphor-bronze is worth only 0.26 as much per pound as soft copper, while its actual market price is greater than that of copper.

Silicon-bronze, of relatively high resistance, requiring 2.17 times the section and weight of copper for equal conductivity, is entitled to little or no consideration as a transmission line material. This alloy, in order to give equal conductivity at equal cost with copper, must sell at only 0.46 of the price of copper per pound. But the price of silicon-bronze is equal to, or greater than, the price of copper, so that the cost of the high-resistance silicon-bronze for a line of given resistance will be more than twice that of copper. For this more than double cost the bronze gives 6.38 times the tensile strength of a soft copper line of equal conductivity.

Taking the market price of steel at one-fifth that of copper, which is amply high for the steel, as a rule, a steel wire of equal conductivity with the copper will cost only 1.6 times as much and will have 26.7 times the tensile strength of the copper, or four times the tensile strength of a wire of equal conductivity made from high-resistance silicon-bronze. From this it is clear that steel offers a cheaper combination of conductivity and strength than does silicon-bronze of high resistance. That grade of silicon-bronze having the lowest resistance may cost 0.98 as much per pound as soft copper, and will have 1.79 times the strength of the copper for equal conductivity. This bronze actually costs more per pound than copper, so that it cannot give equal conductivity at equal cost.

Very hard-drawn copper has a conductivity equal to that of the best silicon-bronze, and the tensile strength of this copper is 17 per cent. greater than that of the bronze. Silicon-bronze costs more per pound than hard copper, but even with equal prices the hard copper gives equal conductivity and higher strength at the same cost. Furthermore, the conductivity of silicon-bronze is much more liable to serious variations than that of hard copper. Between hard-drawn copper and steel there is very little apparent place for any grade of bronze in electric transmission lines.

The hardest copper wire is very stiff, and is more liable to crack when twisted or bent than is wire of only medium hardness. Such medium-hard copper has a tensile strength 34 per cent. greater than soft copper of equal conductivity, and is much used on long transmission lines. Aluminium is the one metal which, for given conductivity in a transmission line, combines a smaller weight, a greater tensile strength, and a higher permissible price than soft copper for the same total cost. For equal conductivity an aluminium wire has a greater tensile strength than one of medium-hard copper, and costs less than copper of any grade when the price per pound of the aluminium is less than twice that of copper, which is usually the case.

These properties make aluminium by far the most important competitor of copper in electric transmission and have led to its use in a number of cases, notably for the two longest lines in the world, namely, between Colgate and Oakland and between Electra and Mission San José, all in California.

It has not been found practicable to solder joints in aluminium wire because of the resulting electrolytic action when aluminium is in contact with other metals. Joints of aluminium wires are usually made by slipping the ends past

each other in an oval aluminium sleeve and then giving the sleeve and wires two or three complete twists, or by a process of cold welding with a sleeve joint.

Long transmission lines are in nearly all cases run with bare wire supported by poles. Where very high voltages are employed no insulation that can be put on the wire will make it safe to handle, and the cost of such insulation would add materially to that of the entire line. It is, therefore, the practice to run transmission lines above all other wires and to rely entirely on the supports for insulation.

Where it is absolutely necessary to run a transmission line for some distance underground or under water the voltage, if very high, should be reduced for that portion. The greatest voltage that it is practicable to carry on a submarine cable is not certainly known, but 3000 to 10,000 volts have been used in some cases, and in one instance at least a cable carrying alternating current at 13,200 volts has been laid for nearly a mile under water.

The considerations thus far noted apply alike to wires carrying continuous and alternating currents, but there are some other factors that apply solely to alternating lines. Owing to the inductive effects of alternating currents in long, parallel wires, such wires should be transposed between their supports at frequent intervals. The induction between wires increases with the frequency of the current carried and decreases with the distance between the wires. According to these conditions, wires should be transposed as often as every eighth of a mile in some cases, and at intervals of one mile or more in others.

An alternating current when passing along a wire tends to concentrate itself in the outer layers of the wire, leaving the centre idle. This unequal current distribution increases with the frequency of the current and with the area of the cross section of the wire. The practical effect of this unequal distribution is to make the resistance of the wire a little higher for alternating than for continuous currents. In existing transmission lines the increase of resistance due to this cause seldom amounts to one per cent.

When an alternating current passes through a circuit, the action termed self-induction sets up an electromotive force in the circuit that opposes the flow of current, as does the resistance of the wire, and this is called the inductance of the circuit. The ratio of this inductance to the resistance of a circuit increases with the number of periods per second of the alternating current used and with the sectional area of the wires composing the circuit. For a circuit of No. 6 B. & S. gauge wire the inductance amounts to only 5 per cent. of the line resistance, but for a circuit of No. 000 wire the inductance consumes as much of the applied voltage as does the resistance.

Both the unequal distribution of alternating current over the cross section of a conductor and the inductance of circuits make it desirable to keep the diameters of transmission wires as small as other considerations permit. As soft copper has greater conductivity per unit of area than any of the other available metals, it clearly has an advantage over all of them as to inductance and increase of resistance with alternating current.

At very high voltages there is an important leakage of energy between the conductors of a circuit, and this loss varies inversely with the distance between these conductors. Thus it happens that inductance makes it desirable to bring the parallel wires of a circuit close together, while the leakage of energy from wire to wire makes it desirable to carry them far apart.

To provide greater security from interruption, the conductors for important transmissions are in some cases carried on two independent pole lines. Even where all the conductors are on a single line of poles it is general practice to divide them up into a number of comparatively small wires to decrease inductance.

Data of a number of transmission lines presented in the appended table illustrate the practice in some of the more recent and important cases as to the materials, size, number and arrangement

SIZES AND MATERIALS OF TRANSMISSION WIRES OF SOME NOTABLE AMERICAN TRANSMISSION LINES. THESE COMPRISE SOME OF THE LONGEST LINES IN THE WORLD

Location of Transmission	Line Voltage	Number Wires	Size of Each Wire B.& S.Gauge	Metal in Wire	Length of Transmission. Miles
Canon Ferry to Butte	50,000	6	0	Copper	65
Colgate to Oakland	40,000	3	00	Copper	142
		3	000	Aluminium	
Electra to Mission San Jose	40,000	3	471,034 C. M.	"	145
Santa Anna River to Los Angeles	33,000	6	1	Copper	83
Apple River to St. Paul	25,000	6	2	"	25
Welland Canal to Hamilton	22,500	3	1	"	35
		3	00	"	37
Canon City to Cripple Creek	20,000	3	3	"	23½
Madrid to Bland	20,000	6	4	"	32
White River to Dales	22,000	3	6	"	27
Ogden to Salt Lake City	16,000	6	1	"	36½
San Gabriel Canon to Los Angeles	16,000	6	5	"	23
To Victor, Colo	12,600	3	4	"	8
Niagara Falls to Buffalo	22,000	12	350,000 C. M.	"	23
Yadkin River to Salem	12,000	3	1	"	14.5
Farmington River to Hartford	10,000	3	336,420 C. M.	Aluminium	11
Wilbraham to Ludlow Mills	11,500	6	135,247 C. M.	"	4.5

of the wires. The sixteen plants of which particulars are given include the greatest power capacities, the longest distances and the highest voltages now involved in electrical transmissions. Each of the lines named is worked with alternating current of two or three phase. Each three-phase line must have at least three wires, and each two-phase line usually has four wires.

On ten of the lines the number of wires is greater than three or four, thus reducing the necessary size of each wire for a given conductivity in the line. The Butte, Oakland, and Hamilton lines are run on two sets of poles for greater security, and a second pole line has been added to the Niagara and Buffalo system to carry additional wires. In the majority of cases where more than three wires have been used, the object has been to avoid inductance and other troubles incident to wires of large diameter.

The largest wire used in any of these lines is the 471,034-circular mil cable for the 145-mile transmission between Electra and Mission San José. This cable has thirty-seven strands and is of aluminium, so that it has 1.66 times the area in cross section of a copper cable of equal conductivity. Of the two longest transmissions in the world, namely, the one of 142 miles to Oakland and the other of 145 miles to Mission San José, the former has one aluminium and one copper line, and the latter is made up of one aluminium line.

On the Niagara line, with 22,000 volts, the wires were strung 18 inches apart. The Madrid and the Hamilton lines, with 20,000 and 22,500 volts, respectively, have their wires 24 inches apart. On the Cripple Creek line the wires are 50 inches apart, and the pressure is 20,000 volts. From Colgate to Oakland the distance between the wires is only 36 inches, though the voltage is 40,000. Between Cañon Ferry and Butte the wires of the transmission line carry 50,000 volts and are 78 inches apart, showing the tendency to increase the separation of the wires at high voltages.

PROGRESSIVE NON-UNION LABOUR

SOME FEATURES OF THE SYSTEM AND MANAGEMENT AT THE BALDWIN LOCOMOTIVE WORKS

By John W. Converse

One of the most conspicuous examples of successful non-unionism in the engineering trades is furnished by the famous Baldwin Locomotive Works, of Philadelphia, the largest establishment of its kind in the world, one in which, with its 13,000 men on the pay-roll, there never yet has been a strike or lock-out, and where opportunity for the development and recognition of worth of the individual worker is afforded to a noteworthy degree. Labour organisations have never been able to gain a hold there, and the whole history of the works admirably illustrates the fact that organised labour in its modern trades union sense is not essential to either the material or the moral welfare of the workingman. Gauged solely by intrinsic merit, many of the Baldwin men have risen from the ranks to positions of trust and responsibility in the firm's affairs, and this fact, more than anything else, bears witness to the progressive and appreciative spirit of the management. It is a noteworthy fact, too, that every one of the present members of the firm was at one time in some subordinate position in the shop or offices of the establishment.

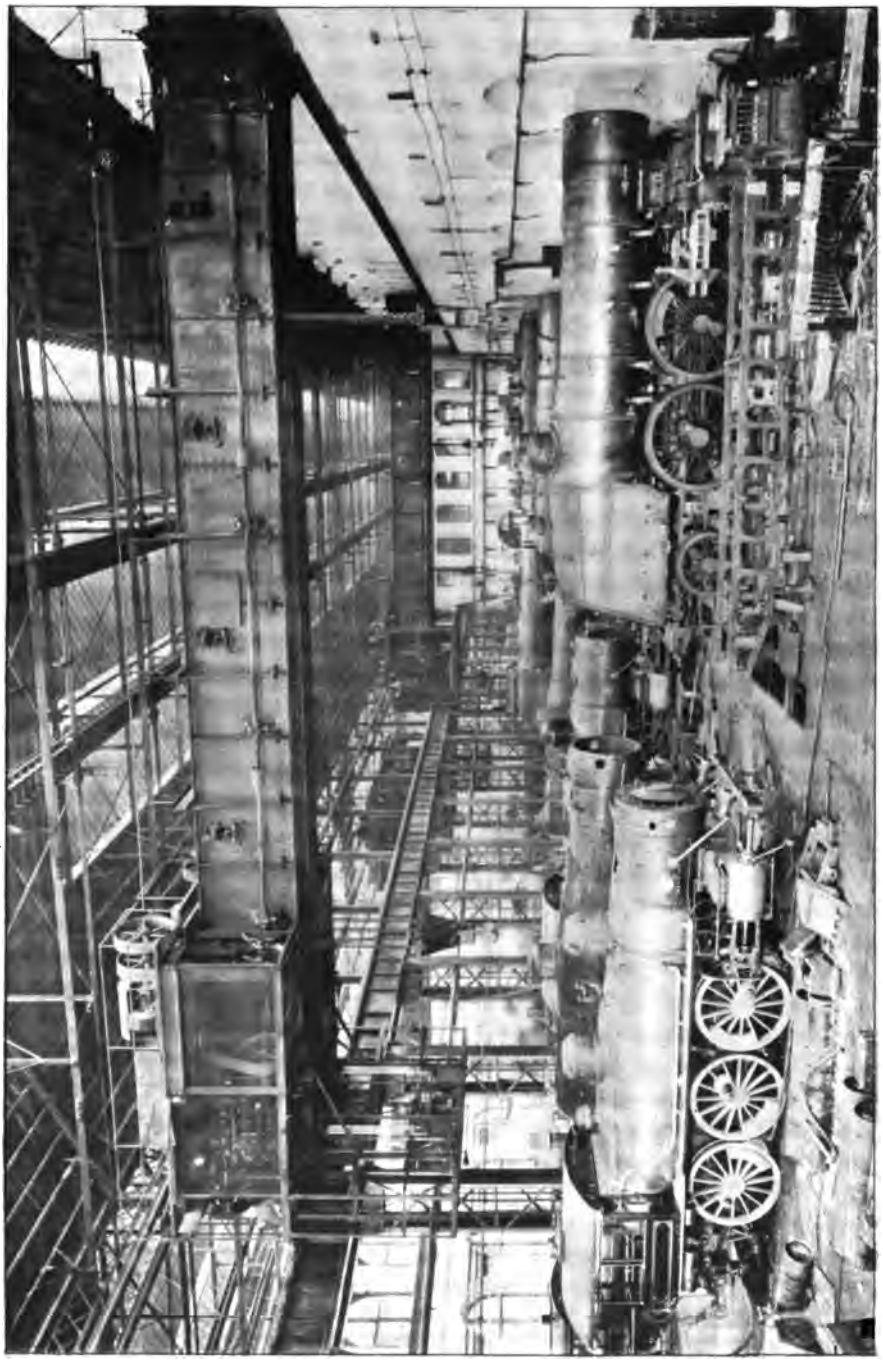
It has long been recognised in these works that it is to the advantage of the employer to pay high wages for good work quickly and accurately done, rather than to pay low wages for slow and slovenly work, and that the largest output from a plant and the best all-around results are secured where the interests of the workingman and of the employer are in perfect harmony. This is not sentiment, but business

The establishment affords an interesting object lesson to the student of social economics, and an account of some of the features of its labour system and management, as recently presented by Mr. John W. Converse, one of the company's officials, in the Annals of the American Academy of Political and Social Science, has therefore been here reprinted.—THE EDITOR.

WHEN locomotives first came into use they were comparatively simple in design and construction. They were built to haul a light load on a level track or on easy grades. As the number of railways increased and the conditions of service became more severe and diversified, the types of locomotives began to multiply, and the process of manufacture became more and more complex. A system of classifying the locomotives constructed was, therefore, adopted. It has been in operation for about fifty years, and forms the basis of the shop practice. The system originally involved the classification of the locomotive by the number of driving wheels and the weight of the engine. As the types multiplied still more, however, it was found that this method did not differentiate the classes sufficiently, and it was subsequently modified. It is now based on the number and arrangement of the driving and truck wheels, and the size and number of the cylinders. The principle resembles that used in botanical scientific nomenclature; the locomotives are reduced to their genus and species by means of a combination of figures and letters which indicates the total number of wheels under the engine, the number of driving wheels, the diameter of the cylinders, and whether they are single-expansion or compound.

In a locomotive of new design every detail must be proved suitable in the drawing room before the work is sent to the shop. Every class of locomotives has different modifications within the class. These modifications may take the form of an increase in the diameter of the boiler, increase in length of piston stroke, and so on. Every such modification is given a drawing number. All the drawings are filed and a careful record is kept of them. In this manner the work of the drawing-room is simplified and new drawings can be produced with the utmost facility.

By this method, also, the work in the shop is simplified. All locomotives of



A VIEW OF THE ERECTING SHOP

MUCH OF THE FORGING IS DONE BY HYDRAULIC POWER

a class and drawing being uniform throughout in their fundamental features, a system of gauges and templates is in use by which such parts of locomotives and such sets of connections as may be desired are made absolutely interchangeable.

The capacity of the establishment is thirty-six locomotives a week. Orders are allotted spaces in the week in which delivery is promised. If a new design has to be made, the drawing must be completed and data submitted to the purchasing department for ordering material before the work is ordered in the shop. All parts of locomotives and tenders, except boiler and tank plates, steel tires and steel castings, chilled wheels, boiler tubes, and special patented appliances, are made from the raw materials. All parts ordered by the purchasing department are ordered for a definite locomotive or a number of locomotives of a particular class, and must be invoiced as such.

The foremen of the different shops where the various component parts of the locomotive are made are furnished a list, bearing the class designation of the locomotives for which the parts made in their shops are intended. When the drawings are furnished them, they allot the work and see to it that it is finished by the time specified on the list. Each part is marked with the class designation of the locomotive for which it is intended. Each workman reports to the time-keeper, through his boss or through the foreman, his time for each piece and the locomotive for which the piece was intended. All these component parts are assembled in the erecting shop at the appointed time, and, by means of this unit system, the finished locomotive is put together without confusion or unnecessary delay.

A further advantage of this unit system of production appears in the accounting department. Two sets of books are kept,—a financial and a man-

ufacturing set. In the financial department accounts are kept of sales, purchases, and expenditures. In the manufacturing books a separate account is opened with each locomotive, and the material entering into its construction and the labour expended on it are charged against that locomotive. At the end of the year these two sets of books must balance each other. By this method the actual cost of each locomotive is obtained with accuracy, and, allowing for fluctuations in price of raw materials, correct quotations can be made for any class of engine.

It is upon this unit system of locomotive classification, by means of which the identity of each locomotive is preserved, that the system of the labour organisation and management of the establishment is based. Having mentioned these points in the method of manufacture, let us glance at the personnel of the men.

A VIEW OF THE SPRING SHOP

About 13,000 men are on the pay-roll of the Baldwin Locomotive Works at the present time. The majority of these are Americans, although representatives of nearly every nationality on the face of the globe are found among them. The only requirements of an employee are a good record, a fair amount of intelligence, and willingness and ability to do the work. About 10 per cent. of the total number employed are boys under the age of twenty-one years. A large proportion of these are apprentices being taught a trade. Strict conformity is observed with regard to the State factory regulation prohibiting the employment of boys under sixteen years old. Boys under that age are taken on only in extreme cases of poverty or distress, and then only if they hold a magistrate's certificate, as required.

A great variety of skilled labour is employed; some of the different kinds are iron-founders, brass-founders, blacksmiths, machinists of all kinds, woodworkers, tinners, carpenters, painters, copper-workers, plasterers, and sheet-iron-workers. A skilled workman is

NOTHING BUT CONNECTING RODS IS HANDLED IN THIS PART OF THE SHOP

A CORNER IN THE MACHINE SHOP WHERE THE CYLINDERS ARE FINISHED

here understood to mean one who is familiar with the use of a tool, a machine, or a process; an unskilled workman is one who cannot run a tool, but does ordinary labouring work. The number of skilled and unskilled workmen is divided in the ratio of about two-thirds skilled to one-third unskilled.

Wages are reckoned by the hour and not by the day. Unskilled labourers have a per-hour rating. Piece-work wages, for convenience in accounting, are equated to a per-hour rate. A piece-worker can earn the equivalent of from eighteen to fifty cents an hour, according to the character of the work and the ability of the man. The average wage of skilled labour is thirty cents per hour. The average wage of unskilled labour is about sixteen cents per hour. The men are paid on Friday for their time in the preceding week. Each man has a number which is assigned to him on entering the employ of the Baldwin Locomotive Works. Each shop has a given block of numbers for its quotum of men. When the whistle blows to stop work at six o'clock on Friday the men in the different shops file by certain booths, each giving his number and receiving his pay envelope, which contains in coin the amount due him and on which is written the name, number, and amount. Payment is made in coin to insure accuracy and a saving of time in making up the amounts.

The shops are run continuously twenty-three hours a day, and the force is divided into day and night shifts. The day shift is on at seven and off at six, with an hour, from twelve to one, for lunch; the night shift goes on at six and off at seven in the morning, having twenty minutes for lunch at midnight, which are not deducted from their time. A monitor whistle blows at three minutes before the hour at seven and one; at the hour each workman is required

FINISHING PISTONS AND CROSSHEADS

THE CABS FOR THE LOCOMOTIVES ARE MADE HERE

to be at his place and commence work when the signal is given. When late, a workman must secure a "late pass" at the office, which must be presented to the watchman at the gate before he is allowed to report for work. A time-worker is fined for being unpunctual, an hour's time for the first hour or fraction thereof he is late. Except in rare cases, men are not allowed to report after 8 A. M. Piece-workers are fined one hour's rate no matter how late they are. Workmen quitting or preparing to quit before the stop signal is given are fined one hour's time. As time is money when so many men are employed, the rules regulating attendance are strictly enforced. The moral effect of the "late pass" on the foreman's desk is quite an aid to punctuality.

Each workman must know before commencing a piece of work that it will finish to the sizes marked on the sketch or card given him, and whether the work is to be completed by himself or others. A rigid system of inspection is enforced in the shops to insure the work being done properly and accurately. Damage for spoiled work is charged to the workman, unless occurring from a reasonable cause, and must be reported at once to the foreman. A workman accepting a piece of work from another to finish is held responsible for any errors in the work of his predecessor. Work must be kept neatly filed and properly marked with the class designation and number of the locomotive for which the piece is destined, and each succeeding workman must see that the mark is continued on work finished by him. All work, as soon as completed at one machine, must be delivered to the next succeeding machine. Economy in the use of material of all kinds, oil, waste, emery, files, etc., is strictly enjoined on every workman.

Each employee is responsible for the tools placed in his charge on commencing work, and upon leaving the employ of the establishment he must deliver the key of his box or drawer to the foreman and satisfy him that the stock of tools is complete and in proper order. Each workman is required to keep his bench, vise, lathe, forge, machine, or whatever tool or place at which he is employed, cleaned and free from rubbish. Careless damage to a tool is charged to the workman.

A workman whose machine breaks down through no fault of his own, or while waiting for work, receives a per hour rate proportionate to his piece-rate, at the discretion of the foreman. A workman running two or more machines on piece-work, however, is not paid an hour rate for time lost by one machine on account of a breakdown, or while waiting for work.

Workmen are required to report to the timekeepers as follows:—Number of hours per day; name of machine; designation of engine or job for which the part is made; when commenced and when finished. Piece-workmen are required to return and charge all their completed work in the week in which it is finished. They do not receive pay for their work unless they comply with this regulation. Piece-workers personally see that timekeepers get their correct time daily; they also must enter on their slates, each evening before leaving the works, their time for the day.

Having glanced at the personnel of the workmen, we will discuss some phases of the system which present themselves. The unit system of production makes it desirable that all work should be turned out by the piece. In the Baldwin Locomotive Works two forms of piece-work are represented, namely, piece-work proper, in which the workman is paid according to the quantity produced; and a contract system, where sub-foremen, called contractors, are entrusted with the execution of a portion of the work on a locomotive; for example, the entire construction of the cylinders, or the erection of a certain number of tanks. The contractor has entire charge of the job, seeing that the raw material is delivered in time, that the men are prompt and diligent, that tools are in repair and machines do not break down. The contractor is paid for the job, the firm paying directly to each workman for the labour on the job. The contractor can-

MAKING BOLTS

not, therefore, get more than the amount due him on any one job by curtailing the wages of his labour. The contractor is a piece-worker on a larger scale. As he is paid by the job, he has an incentive to turn out his work as quickly as possible and to get as much work as possible out of the men under him.

The following occurrence illustrates the value of the contract system in expediting work. Tanks are built exclusively in one of the shops comprised in the works. The frames and bodies are built on the second and third floors and are taken in an elevator to the fourth floor, where they are erected over the trucks. The elevator broke down one day and the job was held up. The contractor was losing money, as he could not turn out his tanks. The elevator was running inside of two days; in the ordinary course of events two weeks would probably have been taken to put it in working order.

The contract and piece-work systems insure quantity of product; a rigid system of inspection insures quality of product. In order to insure good workmanship an extremely rigid system of inspection is maintained, and contractors and piece-workers are held to strict account if the quality of their work falls below the standard. Another feature of the piece-work system, which is at the same time an advantage and a disadvantage, is the specialisation which it naturally entails. In the kind of machine work done at the Baldwin Locomotive Works, the same operation is performed over and over again many times. The piece-worker, doing the same thing repeatedly, soon finds out the best and quickest way to do the work, and, as he can make more money doing his specialty, he is naturally unwilling to be shifted to another machine or another class of work. The tendency of this specialisation is to limit the workman to a single process, and, as a result, the general mechanic has threatened to become practically extinct, to the detriment of manufacturing interests generally.

To remedy this disadvantage an ap-

prenticeship system was inaugurated at the Baldwin Locomotive Works in March, 1901. The apprentices taken on are divided into three classes.

First-class apprentices comprise boys who have had a good common school education and are not over seventeen years and three months of age. They are indentured for four years. An apprentice of this class is required to attend at least two evenings in each week during the first three years of his apprenticeship free night schools, such as during the first year will teach him elementary algebra and geometry, and during the remaining two years shall apprentice is required to attend night schools, which shall teach him the rudiments of mechanical drawing, for the first two years of his indenture.

The third-class indenture is in the form of an agreement made with persons twenty-one years of age or over, who are graduates of colleges, technical schools, or scientific institutions, having taken courses covering the higher mathematics and the natural sciences, and who desire to secure instruction in practical shop work.

The indentures or agreement in each case place upon the firm the obligation to teach the apprentice his art thor-

THE SMITH SHOP FOR LIGHT FORGINGS

teach him the rudiments of mechanical drawing.

Applications for indenture as second-class apprentices are considered from boys who have had an advanced grammar or high school training, and are not over eighteen years of age. The term for this class is three years. The oughly and to furnish him abundant opportunity to acquire a practical knowledge of mechanical business. The firm is also bound to retain the apprentice in service until he has completed the term provided for in the indenture or agreement, provided his services and conduct are satisfactory. In all cases the firm

reserves the right to dismiss the apprentice for cause.

The rates of pay in the different classes are as follows:—

	1st year per hour.	2d year per hour.	3d year per hour.	4th year per hour.
Apprentices of the First Class	5c.	7c.	9c.	11c.
Apprentices of the Second Class	7c.	9c.	11c	
Apprentices of the Third Class	1st 6 months of 1st year, 13c. per hour. 2d 6 months of 1st year, 16c. per hour. 1st 6 months of 2d year, 18c, per hour. 2d 6 months of 2d year, 20c. per hour.			

In addition to the rates mentioned above, apprentices of the first class each receive an additional sum of $125, and apprentices of the second class an additional sum of $100, at the expiration of their full terms of apprenticeship, respectively.

The apprentices are under the direct supervision of a superintendent, and a careful record is kept of the performance of each. The apprentices are put to work in the shop on the different machines,—millers, slotters, planers, lathes, boring machines, and others. They are shifted to a different machine every three months and an account of their work is entered in the superintendent's book. Apprentices of the third class are shifted as often as they wish from one machine to another. On the completion of his indenture, if he wishes it, and his record has been satisfactory, the apprentice can secure a good position at the works, at the start generally as track boss, inspector, or in some such capacity. There are about three hundred apprentices on the books at the present time; about two hundred of them are in the first, about sixty in the second, and about forty in the third class. The object is to turn out good, all-around machinists, and good results are hoped for from the system.

The policy of the firm is to make the interest of the men identical with its own. Hard work is required, but high wages are paid, ingenuity is encouraged, and intelligent and faithful work is liberally rewarded. Piece-rates are seldom cut, and then only on account of the introduction of a time-saving tool, in which case the workman shares in the gain accruing. The policy is to maintain a uniform piece-rate for all the men doing a certain class of work. If one man shows especially marked ability, he may be shifted to another job, usually being made a contractor or sub-foreman. The policy of the establishment is to make promotions from within; foremen, bosses or superintendents are not imported. There are no hereditary rights to important positions.

Strikes are practically unknown. If a man has any grievance he can submit it to the superintendent, and he knows that his complaint will receive careful consideration and that he will be dealt with fairly.

No one is questioned, when he enters the employ, whether he is affiliated with a trades union or not; but trades-unionism does not flourish at the works.

A pleasing and noteworthy feature of the attitude of the men is the *esprit de corps* which prevails. They realise that their employers are doing their best for them and only ask in return the best work of each man. Every man is proud of the establishment he works for, the oldest of its kind in the United States, and every man is proud to be known as a Baldwin man.

A DECADE OF MACHINE SHOP PROGRESS

FROM 1890 TO 1900

By Edward H. Sanborn

REGARDING progress in the line of machine tools and machine shop practice during the ten-year period from 1890 to 1900, the writer, in a recent census bulletin on metal-working machinery, thus summed up the leading features:—

1. The automatic and semi-automatic principles have been extended to new and larger classes of work than before.

2. The forming tool has become a recognised shop appliance.

3. The " oil-tube drill " has been developed from an exceptional to a regularly used tool.

4. Compressed air portable tools have been developed substantially from the beginning.

5. The application of the power press has been greatly extended.

6. Electrical driving has come into general use.

7. The system of heavy portable machine tools in conjunction with a massive iron floor plate has been originated.

8. The grinding machine has been largely increased in size, power, and extent of use.

Closely related to machine shop practice, though scarcely coming within machine-tool classification, may be mentioned:—

9. The development of travelling cranes.

10. The origin of high-speed steels for cutting tools.

These lines of development may be discussed briefly in the order above presented.

The extension of the semi-automatic principle, as illustrated by the hand-operated turret lathe, has been chiefly toward the execution of larger and heavier work, while the use of the entirely automatic turret lathe has been not only in the same direction, but has been adapted to entirely new classes of work. An illustration of the first line of development is found in several types of turret lathes which, although employing certain methods of attacking the work which were not known before their advent, is, nevertheless, essentially an extension of the turret principle to larger work than had before been done by it.

An illustration of the second line of development is to be found in the " magazine feed," full automatic turret lathe. Prior to the advent of this machine the full automatic machine had been employed exclusively for making screws, studs, etc., from bar stock, which was fed to the machine through the hollow live spindle, the pieces being first turned, threaded, etc., and then cut off, when the bar of stock was fed downward and another piece made, the operation continuing until the bar of stock was used up. The new machine applied the automatic principle to the machining of parts which, when in the rough, were already in separate pieces, *i. e.*, castings or drop forgings. In doing such work the finished piece must be taken bodily from the machine and a new rough piece inserted. This is a fundamentally different operation from merely pushing a long bar of stock to a new position. It is effected by the " magazine feed," the magazine being filled with rough parts by the workman, these parts then being automatically inserted in the machine and removed therefrom when finished. The line of development exemplified by the machine

first mentioned belongs to the entire decade, while that exemplified by the other belongs to its close.

Another line of development in this class of machines which should be mentioned is the use of multiple spindles, whereby the output of certain classes of work is very greatly increased,—to the extent of a threefold ratio in some instances. An outgrowth of this development has been the making of small brass screws and similar articles without money consideration, the chips cut off in making the articles being accepted as sufficient payment for doing the work.

The use of the forming tool goes back of the decade under consideration, but its use prior to 1890 was chiefly, if not entirely, for the making of articles from very soft composition castings, examples of the work being seen in the caps of salt and pepper boxes. The application of the principle to harder material came about in connection with the bicycle industry, one of its final applications to articles of steel being in the making of bicycle-wheel hubs. If this is not the first application of the method to steel, at least it familiarised the mechanical public with it, and from this it has come to have quite an extended application.

By the "oil-tube drill" is meant a drill,—either flat or twist,—having an oil tube or oil channel leading to or near its point, through which a current of oil may be forced to lubricate and cool the cutting edges and to wash away the chips. It is used chiefly for deep drilling in steel and usually in machines of the lathe class, in which the work revolves against a fixed drill, although the arrangement is also used in upright drilling machines, in which the tool revolves. The history of this appliance is almost exactly parallel to that of the forming tool. It was known and used to a limited extent before 1890, having first been used for the drilling of gun barrels; but its more extensive application must, like that of the forming tool, be credited to the bicycle industry, the development of the two tools being, in fact, simultaneous. The forming tool having been successfully applied to the machining of the outside of bicycle-wheel hubs, it was found that a portion of the gain due to its faster action was lost because the simultaneous drilling of the hole required more time than the work upon the outside of the piece. This condition of things led to the adoption of the oil-tube drill for this work, and from this application the use of the appliances has become widely extended. Of the two, the oil-tube drill is, no doubt, the more important. The increasing use of hollow-spindle lathes and automatic and hand-operated turret lathes, in which the spindles are necessarily hollow, not to mention milling and other machines having hollow spindles, has given a wide field of usefulness to this tool.

The numerous class of small and unpretentious pneumatic tools which came into prominence and extended use during the decade under review may be looked upon as the most important single machine-tool development of the decade. Of these, the first in order of importance, as well as of time, is the pneumatic hammer. Originally devised as a substitute for the hand hammer and chisel in the machine shop and in stone-cutting, it has extended its field of usefulness to many other fields, and is today an indispensable tool in shipbuilding and in the erection of steel-frame buildings. Of the general class of compressed air tools, the next in importance to the hammer is, perhaps, the rotary drill, which, in its numerous forms and applications, has introduced mechanical power in place of hand labour for classes of work to which the application of mechanical power seemed almost hopeless. These and numerous other applications of compressed air to machine and similar work stand almost wholly to the credit of the decade 1890 to 1900, the hammer alone having been in use prior to 1890.

The great expansion in the use of power presses which has taken place during the decade must be credited largely to the growth of the electrical industries. The advent of the laminated armature for electric generators and motors called for accurately-made punchings of sheet metal of a size and

in numbers previously unknown. The power press furnished the natural method of making them, and in its development the capabilities of the machines were demonstrated as they had never been before.

The electric motor as a means of driving machine tools was first seriously proposed about or shortly before the middle of the decade, and was generally looked upon by mechanical men as a fad of the electrician. The innovation nevertheless obtained a foothold, and advantages which were not foreseen were found to attend it. It has become the accepted method of driving factories which are composed of many departments, the flexibility and economy of the system in distributing power over a considerable area from a central station being here the factor of dominating importance; and also of those factories which are of a nature requiring tools and machines to be located at considerable distances apart, especially if they are also to be intermittently operated. It is also making rapid progress in machine shops, to which the above limitations do not apply, though in such applications opinion regarding its merit is still unsettled. A leading controversial point is the attachment of individual motors to each machine tool *versus* group-driving of several machines through a single motor and a line shaft. There are well-defined conditions under which each method is suitable, but there is still a wide intervening field of debatable ground. As a matter of fact, in this field the individual motor is making rapid progress,—more so, perhaps, than can be readily explained.

Like the increased development of power presses, the floor-plate, portable tool system of attacking heavy work must be credited to the electrical industries, which in this instance, curiously enough, furnished both the work for which the system was first devised, and the means for doing the work. It was to the machining of the ring or magnet frames of large electric generators that the system was first applied, and the electric motor supplied the only practicable method of driving the tools which form part of the system. The system has not yet found much application outside of electrical work, although a beginning has been made.

The grinding machine was first devised during the past decade as a means of doing superior work; but it was not long before it became evident that it was a source of economy, as well as a means of securing superior workmanship. The full significance of this was, however, slow to be realised, and it was not until toward the close of the decade that the movement began toward a very marked increase in capacity, weight, and power of the machine.

In no feature of machine shop practice has there been greater progress during this decade than in the provision of crane facilities. This development is to be credited to the electric motor, without which it is at least doubtful if the present stage of progress could ever have been reached. The mere transmission of the power required for cranes of present capacities by the old square shaft or flying rope would be a serious problem. Electricity furnishes, in fact, an ideal method of driving cranes, and the necessary installation of an electric plant for operating cranes has no doubt greatly furthered the adoption of electric power for other purposes.

As to the innovations of the past few years in the matter of new kinds of tool steels, capable of enduring cutting speeds previously impossible, it is yet too early to state definitely what their ultimate economic importance will be, though it is reasonably certain that it will be considerable.

Current Topics

THE first mechanical invention made by George Henry Corliss, of Corliss engine fame, was a sewing machine for sewing leather,—an invention which, he always claimed, antedated Elias Howe's. According to a paper by Mr. George R. Phillips recently read before the Engine Builders' Association of the United States, it was to perfect this machine and to get it built that Corliss came to Providence, R. I., in the year 1844, applying to the firm of Fairbanks, Bancroft & Co., then doing a machine and engine business in that city. The firm was not long in discovering that Corliss, then about twenty-seven years of age, was such a young man as they wanted in their employ, and they prevailed on him to drop, for the time, the sewing machine and give his attention to other and more important projects on which they were at that time engaged. So valuable did he make himself that within a year he was admitted to the firm, and it was about this time (1846) that he conceived the improvements which have revolutionised the steam engine business and given him a lasting fame. It may not be uninteresting here to refer to the pumping engine which Corliss built and erected for the city of Providence in 1873. It was of unique design, having five horizontal steam cylinders and five horizontal double-acting pumps, evenly spaced around one central vertical shaft. There was no dead centre, no flywheel was required, and there was no limit to the slow speed at which the machine could run. Mr. Phillips said that he had seen it run as slow as one revolution in five minutes. Though a curiosity and in some ways an effective machine, it was a failure as far as the economical use of steam was concerned, giving a duty of but 25,000,000 foot-pounds at contract speed, 25 revolutions per minute. The surface condensation and re-evaporation in the steam cylinders (they were not jacketed) was something excessive.

WHILE everyone concedes the possibility of unforeseen obstacles arising in the installation of a system so prone to difficulties as wireless telegraphy, and while no one would withhold the credit due for the great progress already made in this art, still, in view of the prophecies made over a year ago with regard to the early commercial practicability of transatlantic space telegraphy, the public generally would, perhaps, be justified in expecting that the Marconi Company should now be ready to accept all the business that might be offered. So far, however, from this being the case, the only message that appears to have been transmitted from the United States to

Great Britain is the message of congratulation from President Roosevelt to King Edward, of last January. The reply to this message, to everybody's astonishment, was transmitted by an old-established method, namely, by cable. Some of the excuses for the failure to transmit the King's reply by the wireless system are curious and divergent, not to say amusing. Thus, the manager of the Marconi Company in New York gives the excuse that there was not sufficient electrical energy at Poldhu, England, to transmit the ether waves across the Atlantic; while the Marconi representative in London is reported as saying that his company had refused to transmit the King's reply by the wireless method as a rebuke to the British postal telegraph authorities for the lack of facilities accorded the Marconi Telegraph Company in Great Britain. This, doubtless, in some way refers to the fact that the telegraph is controlled by the government in Great Britain, which does not brook opposition from private overland or over-space telegraph corporations. The latter excuse, if correct, would, however, be so evidently discourteous to King Edward that the lay mind will favour the first explanation as being the more reasonable. As yet the explanation of the lack of power at Poldhu appears to fail when it is remembered that this station was the first of the transatlantic stations established, as it was from this station that Marconi received signals a distance of 2000 miles on shipboard, where the masts were only 150 feet high, and when he was limited to four aerial wires; while at South Wellsfleet, Mass., the masts are over 250 feet high and the aerial wires are innumerable. Furthermore, according to Marconi's recent reported statements, he expects to get along with at least half the voltage which he has been using in his transatlantic experiments.

Some idea of the electric power employed at Poldhu (which station has already earned the title of "thunder factory," owing to the noises and sparks set up by the apparatus), may be gathered from the fact that the electric generator at that station is supposed to have a capacity equal to about 30 horsepower, with an electromotive force of 2000 volts, which is raised by transformers to perhaps 120,000 volts on the aerial wires,—sufficient to give a 12-inch spark and to upset all the untuned wireless stations within a radius of a hundred or more miles. It is said, however, that Marconi expects to transmit messages across the Atlantic with about 5 horsepower. Of course, it is understood that, owing to losses in the transforming apparatus and at the spark gaps, only a small percentage of the initial energy of the dynamo is radiated from the aerial wires.

It might be interesting to inquire how many times the President's message was thrown broadcast upon the ether from the station at South Wellsfleet before it was known that it had been correctly received at Poldhu. This inquiry is suggested by the experience of Mr. Nevil Maskelyne, who was in charge of a wireless station at Porthcurrow, eighteen miles from Poldhu, during the time that the noted tests were made between the latter station and the Italian war vessel *Carlo Alberto*. Mr. Maskelyne's instruments received and copied the calls and messages that were intended for the *Carlo Alberto*, and the records show that the calls were repeated over 200 times and that the messages were repeated by the hour.

To what irrational extremes trades unions will sometimes go in their demands was recently well illustrated in connection with plastering work done at the city hall in New York. When it was discovered that part of the work had been done by non-union men a strike was promptly ordered as a means of compelling their discharge, and on top of this it was demanded that all the plastering finished by them should be torn out and done over again by union

men. Such a thing was once done in connection with the building of one of New York's large hotels. Some one discovered that the marble in the fireplaces had been polished in a yard in which a non-union man was employed. A strike was ordered to have the marble taken out, roughened and repolished by union men and then reset. The proprietors of the hotel unfortunately were in such a hurry to have it finished that they agreed.

AFTER considering the matter of requirements and rules for extra high pressure overhead electric lines, by which are implied pressures of over 5000 volts constant potential, for nearly a year, a sub-committee of the Underwriters' National Electrical Association of the United States has formulated its suggestions and recommendations. Amongst other requirements the subcommittee urges that extra high pressure lines should not approach nearer than a distance equal to the length of the taller poles, or, where this is not practicable, the extra high pressure wires must be carried above the other wires on extra heavy poles, with short spans; and extra heavy cross-arms, pins and insulators, must be employed. Whenever it is feasible to properly separate the extra high pressure lines from the other wires, a grounded screen of wires should be interposed between them, with a current-carrying capacity greater than that of the upper wires and of sufficient mechanical strength to support them. In order to safeguard firemen, the committee recommends that when it is necessary to carry extra high pressure wires past buildings, they must in every case be higher up than the cornice of the building; and the nearer the building, the greater must be their height above the cornice according to a rule given. Thus, if the wires in question approach within 5 feet of the building, they must be at least 8 feet above the cornice. It is also recommended that extra high pressure wires must not occupy the same duct of a conduit, manholes, or handholes, with those of public signalling systems. Evidently, however, some of these recommendations are not favourably received by the various electrical companies, some of whom have asked for a hearing before the recommendations are adopted. It is noticeable that the recommendations relating to the joint occupancy of underground conduits apply only to public signalling systems. It is well known that the American telephone interests have for years been carrying on a campaign against the joint occupancy of high-tension and low-tension lines in the same conduits, and doubtless they will not be satisfied with the limitation to public signalling systems, while probably all the interests operating above 5000 volts will, as far as possible, contest the requirements so far as they apply to them. In the meantime it is understood that the sub-committee will have further time given them for consideration of the subject.

THE council of mercantile marine affairs in Russia has had under discussion measures to develop shipbuilding in that country. It is proposed to issue loans or bounties to shipowners to induce them to build ships at home rather than have them built abroad and to stimulate the purchase of Russian ships built of Russian material. This will be accomplished by a mortgage on the completed vessel at 50 per cent. of the actual cost, without interest, for a period not exceeding twenty years, in equal yearly payments. The cost is ascertained by estimating the expense of building ships in Russia according to certain regulations. The amount of the bounty depends upon the difference between the cost of building ships in Russia and abroad. The loans are issued to seagoing steamships under the following conditions:—Plans and specifications of ships must be presented to the Minister of Finance; the steamers must rank in the highest class, according to the British Lloyds regulations; and the average speed of boats of over 1000 tons register must be not less than 10 knots on six hours' trial; and of under 1000

tons, not less than 8 knots at Lloyds lower load line. To enable shipowners to repay the loans, two measures are proposed, first, the loans will be on long time—twenty years—without interest, and second, the Government will bear part of the expense of insurance. To facilitate the export of Russian goods by steamers built in Russia, it is proposed to allow a rebate of half the expense for Russian coal used on all steamers carrying less than three-fourths of a full cargo on export and one-half of a cargo on import. It is estimated that the unavoidable draughts on the Government treasury by these plans to foster home shipbuilding will not be so large as they would be by payment of direct navigation and shipbuilding premiums. The regulations were discussed at length, and were considered ready to be sanctioned by the Government council, but it was decided that the entire project must first be published in the press of the Empire for remarks, criticisms, or suggestions from persons interested. This is done on account of the diversity of interests involved.

IN a factory employing 1500 men, says the *World's Work*, the labour union made an unreasonable demand upon the owner. The next day a number of old men went to him and said:—"We are sorry that the union did this, and we want you to know that we were not at the meeting." The owner replied:—"Then you are to blame for it. You belong to the union properly; and it is your duty to attend its meetings. If all the best men had attended the meeting, the action of the union would have been wiser. Any demand that all the men in the shop make after careful deliberation is likely to be a reasonable demand." Then he went on:—"Labour unions sometimes have bad government for the same reason that cities have it—the best men do not vote. To be of use, the union should comprise the best men, and they should attend its meetings and direct its conduct." Such an incident as this tells its own story and carries its own moral. It has, no doubt, been parallelled a great many times and is likely to be in the future, and whatever profit is likely to come from it for both employer and employee, will unfortunately come slowly.

WHAT practically amounts to a revolution in the legal status of British trade unions has been accomplished by the final decision in the now celebrated Taff Vale Railway case. The origin of the dispute occurred as far back as August, 1900. At that time differences arose between the directors of the Taff Vale Railway Company and their employees. Out of the 1200 men who went on strike about 800 had contracts with the railway company which they broke in quitting work without notice. The leaders of the Amalgamated Society of Railway Servants, the union to which all the men belonged, seem to have thought that it was a good opportunity to fight the railway company to a finish, and, accordingly, sent down their general secretary, Richard Bell, M. P., from London to direct the strike. It was clearly proved in evidence that Mr. Bell had incited the men who had contracts with the railway company to break them, and had also carried with him from the union headquarters assurances of financial support. The railway company then applied to Mr. Justice Farwell, sitting as a vacation judge, for a temporary injunction restraining the Amalgamated Society and its agents, Bell, the general secretary, and James Holmes, the local secretary, from conducting the strike in an illegal manner, pending the trial of an action against the same parties to make the injunction perpetual.

THE legal vicissitudes of the case are interesting to follow. The Amalgamated Society, contending that as it was not an incorporated body, but merely a voluntary association, it could not be sued in its registered name, carried the case to the Court of Appeal. This court held

the point well taken, and reversed Mr. Justice Farwell's decision, dissolving the temporary injunction on November 21, 1900. The railway company then appealed to the House of Lords,—the highest legal tribunal in the realm. The House of Lords, in turn, reversed the decision of the Court of Appeal, with the trenchant remark, by Lord Halsbury, the Lord Chancellor, that, "if the Legislature has created a thing which can own property, which can employ servants, and which can inflict injury, it must be taken, I think, to have impliedly given the power to make it suable in a court of law for injuries purposely done by its authority and procurement." Whereupon the case was remitted for trial on the main action before Mr. Justice Wills and a jury. The trial lasted fourteen days, and the jury, without leaving the box, found that all the defendants had conspired together to molest and injure the plaintiffs in their business by unlawful means, that the defendants had unlawfully persuaded the men whose notices had not expired to break their contracts, and that they had authorised and assisted in carrying out the strike by unlawful means. The question of damages was left to the judge to assess; but, taking costs and damages together, the verdict will probably take not less than £50,000 out of the accumulation of £250,000 possessed by the Amalgamated Society of Railway Servants.

BROADLY speaking, the effect of this decision is to place the funds of British trade unions at the mercy of courts and juries in actions for conspiracy, negligence or libel. It imposes upon the general officers of such unions severe restrictions in interfering in the local disputes between employers and employees. It establishes as a rule of law, binding upon all the courts of Great Britain and Ireland, that while a strike in itself may be perfectly legal and an acknowledged method of coercion for obtaining higher wages or shorter hours, any combination between the strikers and outsiders may go beyond the scope of the Trade Union Act of 1871, and may become at once an illegal conspiracy under the Common Law. It also puts in pledge the strike funds of any trade union which assumes to make a contract on behalf of its members, and makes this money subject to attachment for damages in case of the deliberate infraction of the terms of the agreement. On the face of it this seems a great victory for employers as against employees; but it must be remembered that the knife cuts both ways, and would be equally applicable to employers should they transgress the law in a similar manner. If, in the words of Lord Justice Lindley, in a previous case, "you cannot make a strike effective without doing more than is lawful," then effective strikes in Great Britain may have had their day, and their place may have to be taken by some new method of collective bargaining. There would be nothing to regret should this prove to be the case, since it may be safely asserted that strikes never result in the compensation of workmen for lost time, and, through trade demoralisation, often seriously cripple the business of employers for months or years afterward,—witness the great engineering strike in Great Britain in 1897.

IT is also interesting to speculate on the effect that this decision of the House of Lords may have on future decisions in the United States. It must not be forgotten that all combinations, whether of employers or employees, are, under the Common Law, conspiracies in restraint of trade, and that all such combinations are legal only so far as they are exempt by statute law from the operation of the Common Law. Neither must it be forgotten that the basis of the legal systems of the United States and of the several States, with the exception of Louisiana, is the Common Law, so that it would not be remarkable if the American courts were to follow the precedent set by the British courts in this instance. In one respect, indeed, the United States courts have already been much more

radical in their action than the British courts. "Blanket" injunctions of the most sweeping character have been granted by these courts against unions and individuals on strike, or assisting strikers, who have attempted to interfere with interstate commerce, and infractions of these injunctions have been summarily punished on the charge of being guilty of contempt of court. But, so far as is known, no attempt has hitherto been made in the United States courts to attach the accumulated funds of trade unions for damages committed by them or their authorised agents.

WHILE it is a matter of history that the first locomotive made and run in England was a small model of an ordinary road locomotive constructed in 1784 by William Murdock, it is probably little known that this original engine is still in existence, and has, within the past year, been exhibited in London by Messrs. Tangyes, Limited. The little locomotive is about 14 inches high and 19 inches long, with a width over the driving wheels of 7 inches. The annexed reproduction of a recent photograph of it illustrates its make-up very clearly. There is an oblong board, mounted upon three wheels, with two driving wheels at the rear attached to a crank axle, and one steering wheel in front arranged under the board, and running in a swivelling fork, which can be set by a tiller handle above. Behind the driving wheels is the boiler, which is a rectangular vessel, 3⅜ inches high, 4¼ inches long, and 3⅛ inches wide, made of copper. Through the boiler a flue passes obliquely, contracting from a circular chamber forming the fire-box to a small funnel in the top of the boiler, which serves to carry off the products of combustion from a spirit lamp, arranged to burn within the fire box. The steam cylinder of the engine is mounted on the top of the boiler and the lower part passes into it, and is surrounded by steam. The piston rod passes upward, and is attached to the end of a vibrating beam, which passes to the front of the carriage and is pivoted in an upright pillar. The diameter of the piston is ¾ inch, and the length of its stroke is about 2 inches. As the piston moves up and down, it causes the beam to rotate the driving wheels by means of a connecting-rod attached to the crank axle. A leaden weight is placed above the steering wheel to balance the machine, and to prevent it tipping over when water is in the boiler.

IT may not be amiss here to repeat the brief account, frequently referred to in the past, given by Dr. Smiles, in his "Lives of the Engineers," of Murdock's

THE FIRST LOCOMOTIVE MADE IN ENGLAND. A WORKING MODEL CONSTRUCTED BY WILLIAM MURDOCK IN 1784

early trials with his little engine. He had made several experiments with it in his house at Redruth; but at length he determined to try it out of doors, on which occasion, small as the engine was, it fairly outran the speed of the inventor. In Dr. Smiles' own words, "one night, after returning from his duties at the mine at Redruth, Murdock went out with his model locomotive to the avenue leading to the church, about a mile from the town. The walk was narrow, straight, and level. Having lit the lamp, the water soon boiled, and off started the engine, with the inventor after it. Shortly after he heard distant shouts of terror. When he came up to his machine he found the vicar in great fear, thinking that the hissing, spitting

little demon was no other than the Evil One himself." When James Watt, with whom Murdock was associated in some of his work, heard of Murdock's experiment, he became alarmed that Murdock's energies might be distracted from the business of stationary engines in which they were engaged, and he requested his partner, Boulton, to remonstrate gently with Murdock and get him to drop the project. Accordingly Murdock did so, never taking up the subject again. The model had been continuously in possession of the Murdock family until 1883, when it was purchased from Murdock's grandson by Messrs. Tangye, of Birmingham, and lent by them to the Melbourne Exhibition of 1889. Subsequently it was placed in the Birmingham Art Gallery, where it remained up to the time of its recent exhibition in London.

IT is well known that the electric transmission of power can be more efficiently effected by the alternating current than by the direct current, because of the ability to utilise step-up transformers, by means of which the current may be transmitted over the line at a high pressure and low current strength, and, at the distant end, may be transformed by step-down transformers to a low pressure and heavy current, such as is used, for instance, to operate electric traction motors, incandescent lights, and to charge storage batteries. As, however, direct current is used to operate traction motors, and to charge storage batteries, it is necessary to rectify or convert the alternating current into a direct current before it can be thus utilised. For this purpose various devices are employed, such as the motor generator and the rotary converter, the latter being a machine in which the alternating current is received at one terminal of the armature of the converter, which current serves to operate the armature as a motor, and at the same time to rectify the current, which, thus rectified, is delivered at the other terminal of the armature as direct current. As an example of the utility of such machines it may be mentioned that the great bulk of the electric power employed by the electric traction companies of New York City is transmitted by alternating current at a pressure of about 7000 volts through cables from the central power station to various sub-stations in different parts of the city, where, by means of rotary converters, the alternating current is converted into direct current at a pressure of about 500 volts. At this pressure the current is used to operate the car motors and to charge storage batteries. These batteries, in turn, are made use of to supply current to the car motors during the "rush" hours and the very dull hours of service. These machines, while fairly efficient and very useful, in view of the large extent to which by their use it is feasible to employ the alternating current for high tension transmission, are virtually as expensive and as large as dynamo machines of the same capacity.

THE recently announced invention, therefore, of an alternating current rectifier, in which the space occupied, cost of construction, and complexity are a mere fraction of those of existing rectifiers of equal capacity, is of much importance. The invention in question is due to Mr. P. C. Hewitt, who is already well known as the inventor of the Hewitt mercury-vapour tube light, which was briefly described in these columns several months ago. Mr. Hewitt's newest device, to which the name of static or stationary converter has been applied, is an outcome of his extensive experiments with mercury-vapour tubes, and its essential feature is the employment of the known property of vapour tubes by which one sign of an alternating current in passing through such a tube is suppressed. In other words, such a tube permits the passage of a current in but one direction, the electrodes seemingly acting as "electric valves," opening, as it were, to permit the current to flow in one direction through the tube, and closing to suppress its flow in the

other direction. One of the static converters already constructed by Mr. Hewitt for testing purposes consists of a glass vapour globe, 7 inches in diameter, 9 inches long, and weighing about three pounds. At the top of the globe there are four finger-like projections, through each of which passes a sealed-in electrode. Attached to the end of each electrode, within the globe and near its top, is an inverted iron cup or thimble, four cups in all. At the lower end of the globe there is a mercury electrode. Three of the upper electrodes are connected outside of the globe to the three wires of an alternating-current circuit; the fourth upper electrode is used for starting the current through the globe, practically as is required in the case of the Hewitt lamp, it having been found that a higher electromotive force is necessary to start the current through such tubes than is required after the current has been started. The mercury electrode is connected to one wire of an ordinary two-wire, direct-current circuit, the other wire of this circuit being connected to the neutral point of the winding of the generator or transformer. The current then enters the upper electrodes as an alternating current; but as one of the signs or polarities of the current is suppressed in the tube, the current passes out at the lower electrode as a pulsating direct current. The fact that the current delivered is a pulsating one is not, however, detrimental, unless the rate of pulsation should be so slow as to cause a flicker on lamp circuits, which result can be readily guarded against, and, on the other hand, such a current is of advantage in charging storage cells.

ACCORDING to data thus far published, this three-pound converter has a capacity of about 8 kilowatts, or 10.8 horse-power. A rotary converter of similar capacity would weigh about 600 pounds. This machine has operated 180 sixteen-candle-power lamps at full candle-power, and experiments have indicated that the pressure at the lower terminals of the globe is uniform, regardless of the strength of current that may be passing through the globe. The converter has already been tested with pressures of 600, 1800, and 3000 volts at its upper electrodes, and its efficiency appears to rise with the voltage, the efficiency at 110 volts being about 86 per cent.; at 600 volts, 95 per cent.; and at 1800 volts, 99 per cent. This implies a drop of about 14 volts between the upper and lower electrodes, at all pressures,—results which, it is expected, will soon be improved upon. It remains to be seen what success converters of this type will meet in regular practice, and also to what extent their capacity may be increased beyond the figures quoted. Their development in this and other directions will certainly be watched with much interest.

AN adverse decision was recently rendered in the United States by a New England court in a suit brought by the Bell Telephone Company against an independent or opposition telephone company, for infringement of the Berliner patent for a telephone transmitter, which patent covered the use of electrodes in constant contact. This patent was filed in the United States Patent Office fourteen years before it was issued, namely, in 1891. The Bell Company, by virtue of the original Bell patent of 1876, which covered the use of the undulatory current for the electrical transmission of speech, and by means of the Blake transmitter patent, had been able to maintain a practical monopoly of the telephone business in the United States for over seventeen years, or up to about 1891, and the Berliner patent, if held to be valid as covering all forms of carbon transmitters, as was claimed by the Bell Company, would have practically continued that monopoly for another period of seventeen years. This fact, together with the delays in the issuance of the Berliner patent, excited public opinion and led the government to institute a suit to ascertain whether the patent had been fraudulently obtained. The decision of the court in this case was that the

patent had been obtained without fraud. The validity of the patent, however, still remains to be settled. This question was of such vital importance to the independent telephone companies, which represent investments in the United States amounting to over $200,000,000, that the defence of the suit was undertaken by these interests. The decision as rendered by the court does not declare the patent invalid, but holds that the defendant companies do not infringe the Berliner patent, inasmuch as the latter covers only solid metallic contacts, while the defendants employ loose carbon contacts, or the microphone principle, in their transmitters; but unless the case is appealed and the decision reversed, which is not generally considered probable, this decision is equivalent to an invalidation of the patent in question.

THE principle of the carbon microphone, which,—always interesting,—has assumed much importance through this decision, was discovered by Professor Hughes, who announced his discovery in a paper read before the Royal Society in 1878. The Hughes microphone consists of a carbon pencil, pivoted loosely at both ends in carbon receptacles, supported by a thin sounding-board attached to the side of a solid block. When the pencil is made part of an electric circuit containing a small battery and a telephone receiver, the slightest friction against the block is amplified manifold. Even a fly walking on the block is distinctly heard, and a small cotton ball let fall upon the block makes a noise like a cannon ball falling on a wooden floor. Many theories have been advanced in explanation of the action of the microphone, but none of them has been generally accepted. The court before whom the Berliner case was tried was satisfied that the action was due to the remarkable effect of sonorous vibrations in varying the electrical resistance at a loose contact between solid electrodes, and as this is the principle which the defendants employ in their transmitters, and as it was discovered by Hughes, and not by Berliner, they are held not to infringe the Berliner patent. It may be noted that Professor Hughes gave his discovery of the microphone to the world gratis.

PERCIVAL ROBERTS, JR.

A BIOGRAPHICAL SKETCH

By James Christie

FOR the past twenty-five years the record of Mr. Percival Roberts, Jr., has been so indissolubly connected with the growth of the famous Pencoyd Iron Works, at Pencoyd, near Philadelphia, that the name of one necessarily implies the thought of the other.

Mr. Roberts was born in Philadelphia in 1857, his parents being Percival Roberts and Eleanor Williamson Roberts. His paternal ancestors were of Welsh origin, descending from John Roberts, who came from Wales and settled in Pennsylvania in 1682. The Roberts family settled in Lower Merion Township, Montgomery County, near the border of Philadelphia County, and on the upland above where the Pencoyd Iron Works now stand. The ancestral homestead and lands are still in the possession of the Roberts family, and a large portion of the original holdings has never changed ownership since the first occupation.

His mother was a descendant of Duncan Williamson, a Scotchman, who settled in Philadelphia about the same time with John Roberts. Both branches of the family, therefore, belonged to the early settlers who followed the fortunes

of William Penn in his endeavour to establish the principles of popular rights and human freedom on this continent.

Young Roberts studied at the Episcopal Academy, in Philadelphia, until he arrived at the age of thirteen. The winter of 1870-71 was spent with Prof. Samuel J. Gummere, at Haverford College, Pa., as a private pupil. Entering Haverford College at the close of 1875, his course was interrupted by illness. He subsequently entered the class of 1876 at the University of Pennsylvania; but after remaining there a few months returned to Haverford and graduated in 1876 as A. B., standing second in rank in his class for the four years.

The summer and fall of 1876 were spent as a volunteer assistant on the Geological Survey of Pennsylvania. In November, 1876, he began the practical work of his life by entering the service of the Pencoyd Iron Works as a mill clerk, with only a slight interruption, which occurred during the year 1877, when he took a post-graduate course in chemistry and metallurgy at the University of Pennsylvania. In the first ten years of his practical career he was always to be found in the ranks of the toilers,—at the puddling furnace, at the mill and the forge,—until the minutest detail of the business was fully understood by him. During those years the grey crush-hat and the leather jacket were always in evidence, late and early, with but few interruptions for holidays.

Dating back to the Centennial year, Pencoyd was a humble iron mill nestling on the banks of the Schuylkill, and held a minor place amongst the iron works of Eastern Pennsylvania. The works originated in 1852 from the union in partnership of two young men,—cousins,—Percival and Algernon Roberts, the former the father of the subject of this sketch, and the latter the brother of the late George B. Roberts, president of the Pennsylvania Railroad.

The works had a slow, but steady and conservative growth, partaking of the character of its founders who believed in steady industry and prudent business methods as the only proper foundation on which to build up a permanent industry. The evidence of this can be seen from the fact that the original total capital invested in the creation of these works was the modest sum of $5000. From that day forth not a dollar of added capital was invested, and the great establishment, whose value is now estimated in many millions of dollars, grew and developed from the results of this original financial investment, together with the constant industry and application of the proprietors. It may be mentioned, in passing, that the word Pencoyd is of Welsh derivation, and is variously translated as "tree-tops" or "head of the woods."

For a few years following the Centennial year the industrial depression prevailing in the country prevented any notable extension of the works. They had entered the ranks of the structural mills in 1875 by preparing for and rolling the structural material for the buildings of the Centennial Exhibition. About 1880, when the tide of depression was rolling away, Mr. Roberts had acquired sufficient familiarity with the business to enable him to lay the lines for its future growth and development. Old mills were consigned to the scrap heap, and new and modern machinery took their place. Shops and foundries for future maintenance and development were provided. About this time it was becoming evident to the intelligent observer that steel would inevitably replace puddled iron as the predominant structural metal, and the important question was, what kind of steel would prevail? Would it be the product of the Bessemer converter, or of the open-hearth furnace? With the conservatism that was a family instinct, this decision was not reached hastily, and sufficient time was allowed to elapse until the trend of events demonstrated in favour of the latter, when the addition of open-hearth furnaces to the Pencoyd Iron Works was inaugurated.

From time to time this plant was torn out and rebuilt as new developments and new ideas proved such a course to be desirable. Experiments were constantly being maintained at the works, without interfering with their normal output

and product, and when these experiments indicated the desirability of a change of methods or appliances the alterations were at once effected. The steel department of these works was the first to try the continuous open-hearth process, in which molten cast iron was the exclusive raw material used.

About the year 1886 it became evident that a bridge manufacturing plant should be attached to the Pencoyd Iron Works, and the beginning of the extensive shops which now form the bridge and construction department was initiated. The same close study and attention that was given to the mill department by Mr. Roberts was extended to the bridge department. Shops were erected, torn down, remodeled, and rebuilt; the best machinery for the intended purpose that could be devised was provided; obsolete tools and machinery were scrapped to make room for more productive appliances, until this department attained a reputation for quantity and quality of output that was not only national, but world-wide.

As soon as the electric dynamo had developed into a practical machine it was adopted for use, Mr. Roberts being amongst the first in the country to avail himself of the genius of the early electricians in the application of the electric generator to lighting and the distribution of power.

It was always a marvel to his competitors how such a quantity of product could issue from the limited area that was available for the purpose. The secret was that all shop areas were utilised to the best advantage. Manual labour was supplemented by mechanical aids that facilitated the efforts of the workman and rendered his toil less arduous. The rapid and economical production of bridge structures was stimulated by exact and systematic methods of operations, and as opportunity arose to make tenders for European work Mr. Roberts demonstrated that foreign manufacturers could be successfully competed with on their ownground.

After the British arms had broken the power of the Mahdi on the Upper Nile, it became a most important matter to extend the Nile railway to Khartoum, and the Egyptian Government found it desirable to bridge the Atbara River near its confluence with the Nile. Tenders from British shops required periods for completion varying from six months to one year, with correspondingly high prices for its execution. One morning a cable despatch was received by Mr. Roberts, giving an outline of the requirements and soliciting proposals for the Atbara River bridge. Within a few hours a reply was cabled, offering to have the completed structure loaded on shipboard within six weeks from the date of the contract. The proposal was accepted, and the seven bridge spans, each of 150 feet, were on the ocean within the time specified,—this despite the fact that, owing to local conditions, the Atbara bridge involved a special design, and complete drawings had to be made for the novel form of structure. It is evident that work performed with this promptness and celerity implied the existence of a working organisation in all its departments of the highest order of skill. It was a striking tribute to the high qualities of leadership exercised by Mr. Roberts.

When the American Bridge Company was formed by the combination of a large number of leading bridge works of the country, the logic of events pointed to Pencoyd as the leading factor, and to Mr. Roberts as the man to take the helm. He became the president and the controlling power in the company until its absorption by the United States Steel Corporation, in which he became a member of the executive committee, retiring, later on, from active participation in this work.

Mr. Roberts was always popular and esteemed by all classes of his employees. Anyone, however humble, could interview him freely, and he was always in full sympathy with every measure intended to benefit the workmen. He was always ready to discuss grievances, whether fancied or real, and the fruits of this are best indicated by the fact that a workmen's strike of serious character never occurred under his management.

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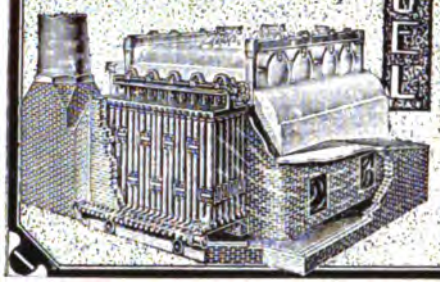

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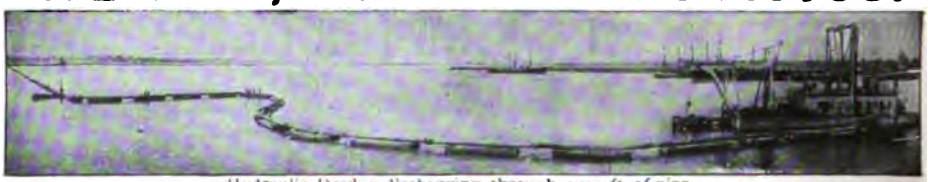

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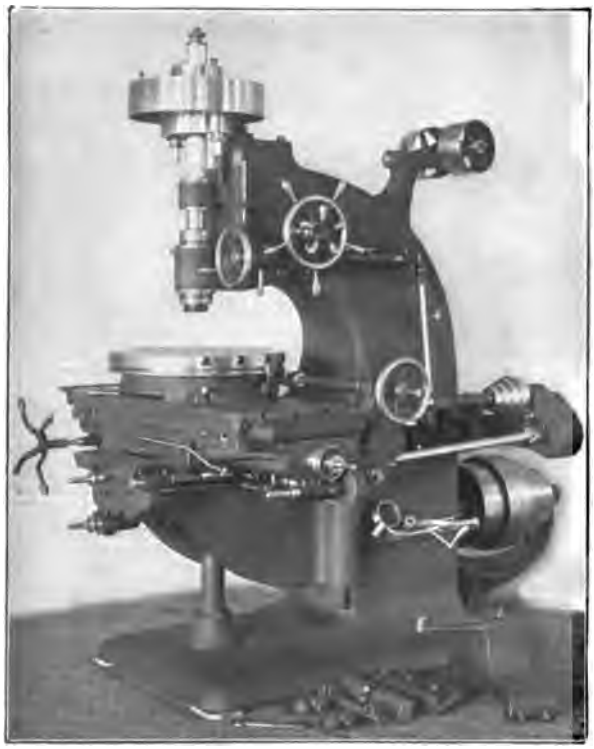

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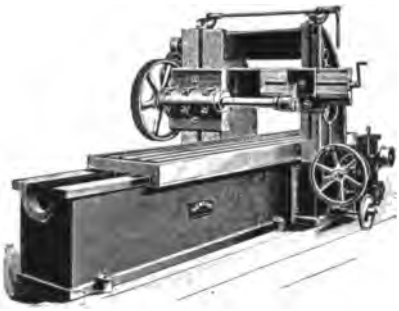

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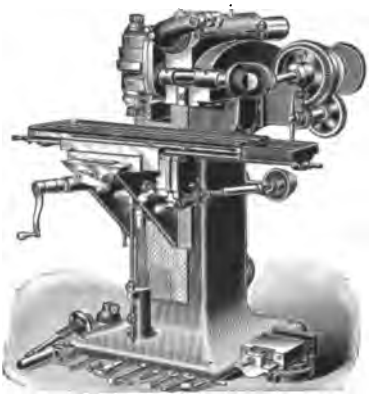

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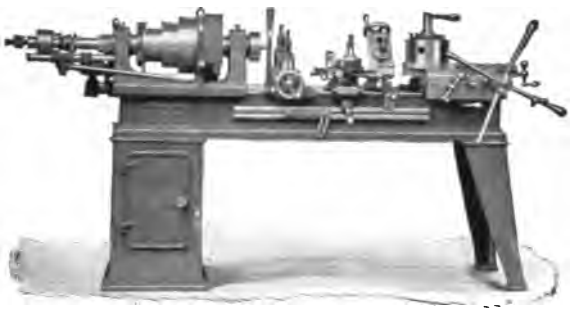

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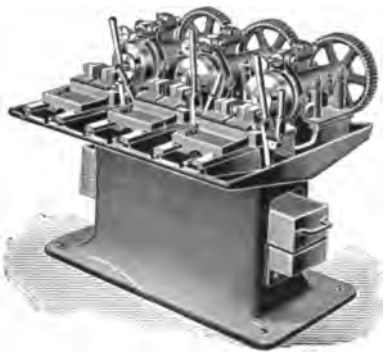

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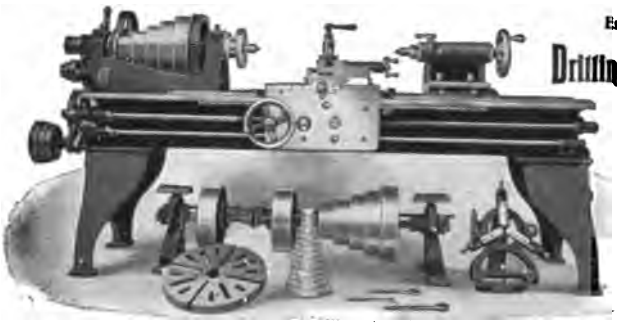

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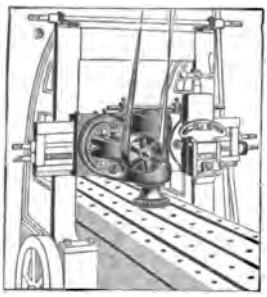

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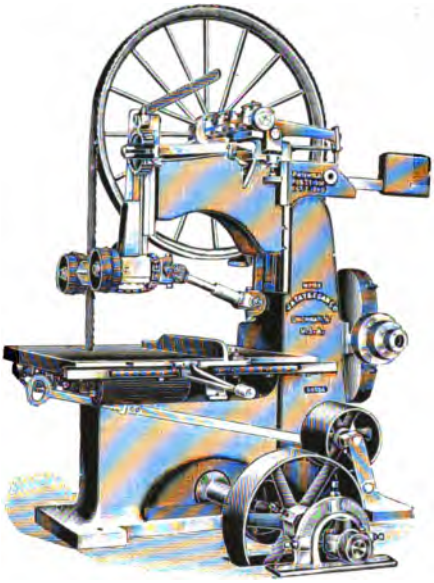

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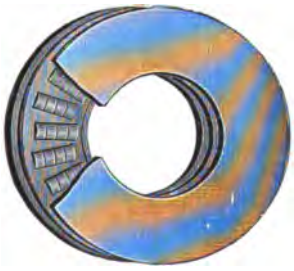

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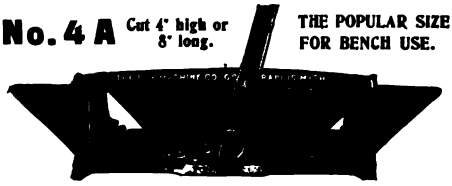

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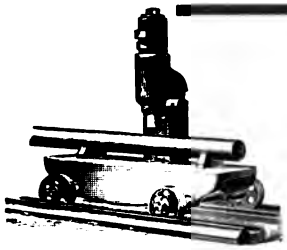

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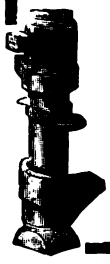

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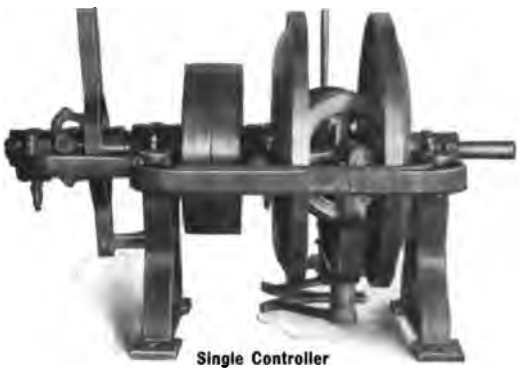

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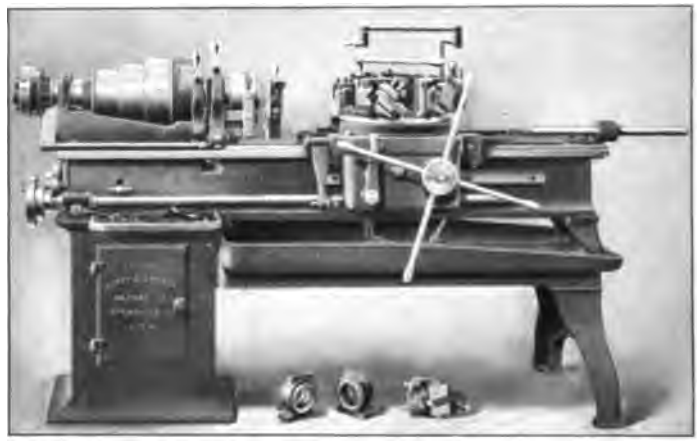

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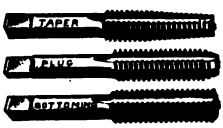

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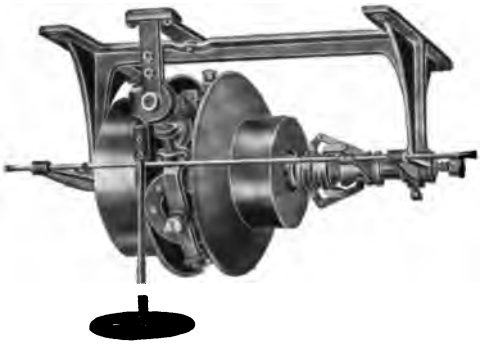

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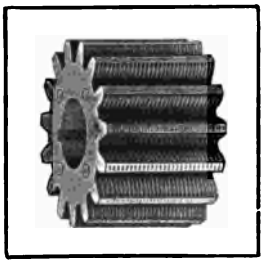

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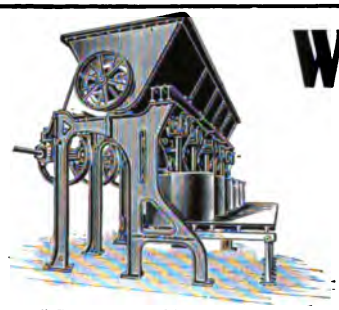

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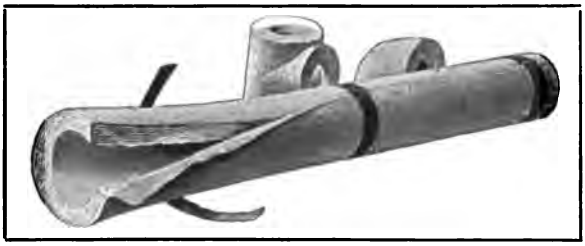

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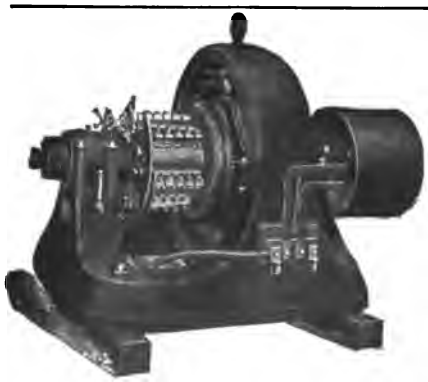

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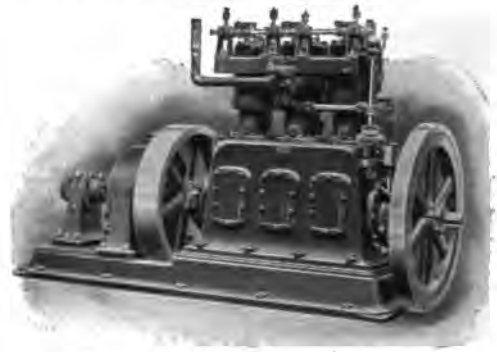

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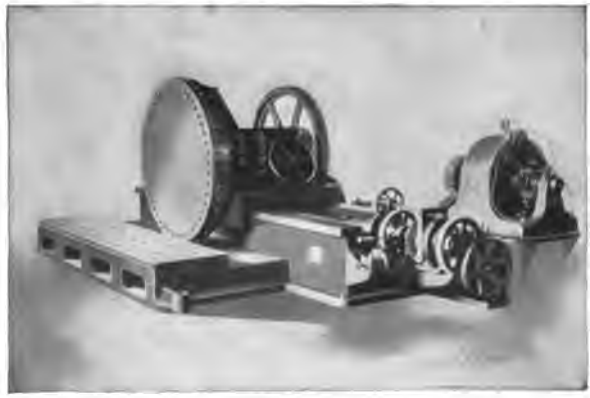

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	Teleph. Engineer		Teacher
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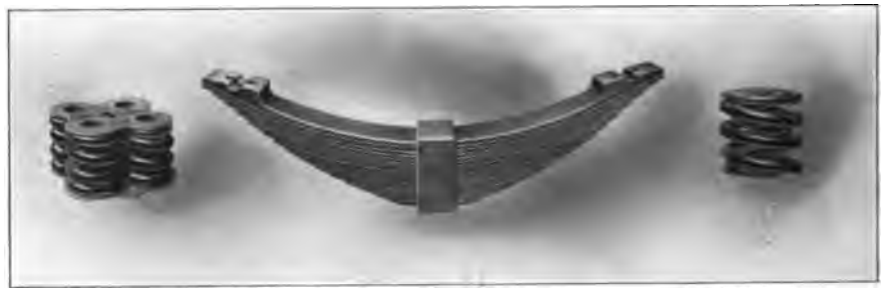

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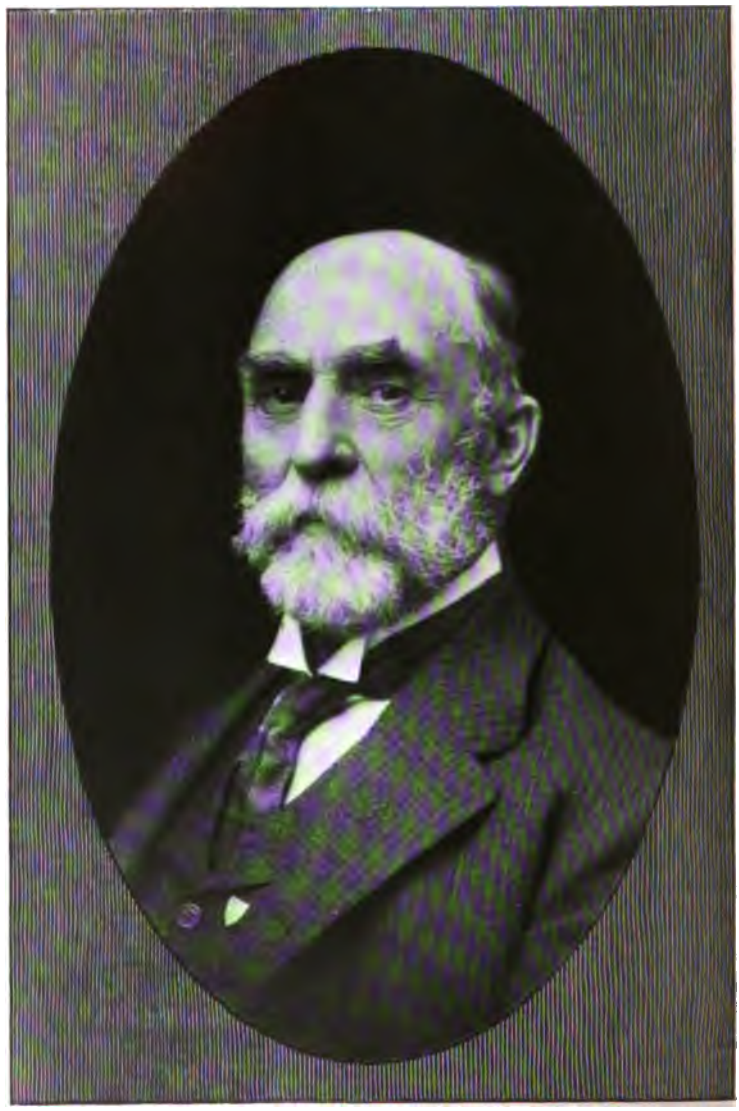

PHOTO BY E. C. DINTURFF, SYRACUSE, N. Y.

W. B. Hazen

SEE PAGE 767

CASSIER'S MAGAZINE

VOL. XXIII APRIL, 1903 No 6

WATER POWER IN SOUTH AFRICA

ELECTRICITY FROM VICTORIA FALLS

By Francis Fox.

IN November, 1855, when Dr. Livingstone and Mr. Oswell reached the Zambesi, the wondrous falls of that river were, for the first time, looked upon by European eyes, and these British travellers gave to them the name of the much lamented Queen. They had often heard of the falls, known by the natives as Mosi oa tanya" (" Smoke does sound there") since they first entered the country; but the exact locality was not accurately known. In fact, the natives regarded the falls with such awe that they viewed them only from a distance, whence they could observe the great columns of spray and hear the distant roar as the cascade fell into the stupendous gorge. In their simplicity the natives supposed that the spray was smoke, and they asked Dr. Livingstone whether in his country there was such a thing as " smoke that sounds."

It is a remarkable fact that, in well-executed maps based on Portuguese discoveries, dated 1662, copies of which are to be seen in the British Museum, the general course of the river " Zambere," which doubtless is the same as " Zambesi," is shown, and the position also of gold and diamond fields is indicated; and not only the sources and course of the Blue and White Niles and the two large lakes or Nyanzas from which they flowed, but also the river Zaire or Congo flowing out from a lake and making its great bend by the Aruimi, whilst on the other hand, a mythical statement appears thereon to the effect that in Tanganzika or " Zaire Lacus," as it was then known, " Tritons, Mermaids and Sirens are said to be." The great discoveries of Speke and Grant, of Livingstone, Baker, and Stanley, were, in fact, re-discoveries of things which had been ascertained and mapped out by the Portuguese and afterwards lost.

Approaching the falls from the north, Dr. Livingstone's description of his visit is well worth recording:—

" After twenty minutes' sail from Kalai, we came in sight, for the first time, of the columns of vapour, appropriately called ' smoke,' rising at a distance of five or six miles, exactly as when large tracts of grass are burned in Africa. Five columns now arose, and, bending in the direction of the wind, they seemed placed against a low ridge covered with trees; the tops of the columns at this distance appeared to mingle

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A BIRD'S-EYE VIEW OF THE GREAT CATARACT OF THE ZAMBESI AND OF THE ZIGZAG CHASM BELOW THE FALLS THROUGH WHICH THE RIVER PASSES OFF

BY PERMISSION OF MR. JOHN MURRAY, LONDON

with the clouds. They were white below, and higher up became dark, so as to simulate smoke very closely.

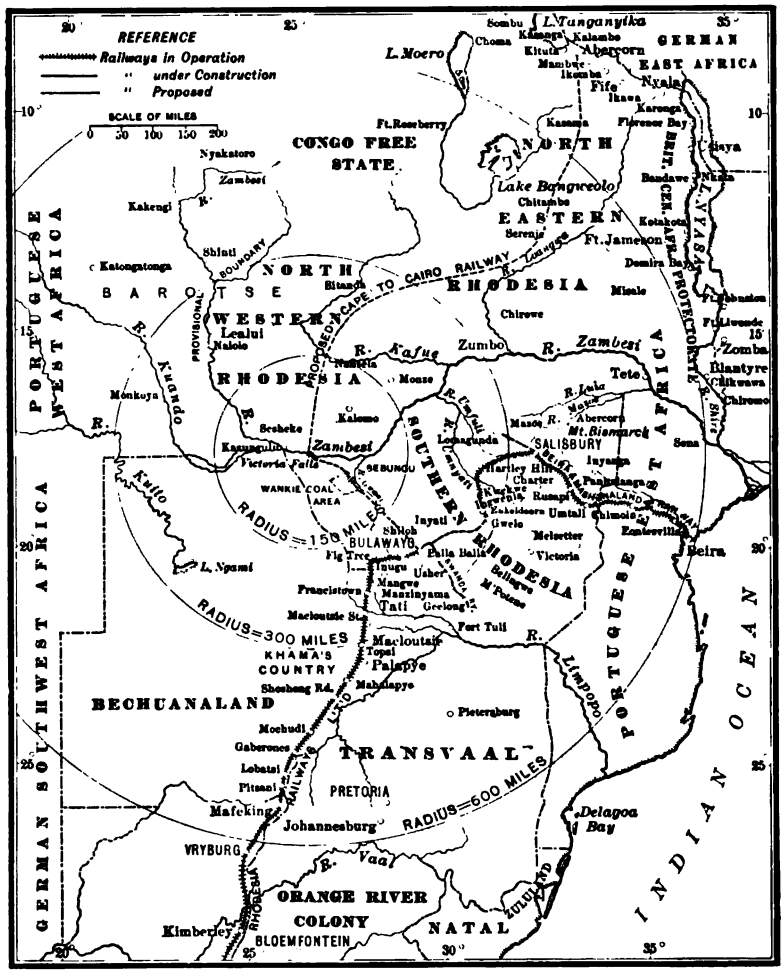
"The whole scene was extremely beautiful; the banks and islands dotted over the river are adorned with sylvan vegetation of great variety of colour and form. But, though we had reached the island in the middle of the falls, and were within a few yards of the spot, a view from which would solve the whole problem, I believe that no one could perceive where the vast body of water went; it seemed to lose itself in the earth, the opposite lip of the fissure, into which it disappeared, being only 80 feet distant. At least I did not comprehend it until, creeping with awe to the verge, I peered down into a large rent, which had been made from bank to bank of the broad Zambesi, and saw that a stream of a thousand yards broad leaped down a hundred feet, and then became suddenly compressed into a space of fifteen or twenty yards. The entire falls are simply a crack made in a hard basaltic rock from the right to the left bank of the Zambesi, and then prolonged from the left bank away through thirty or forty miles of hills.

"In looking down into the fissure on the right of the island, one sees nothing but a dense white cloud, which, at the time we visited the spot, had two bright rainbows on it. From the cloud rushed up a great jet of vapour exactly like steam, and it mounted 200 or 300 feet high; there condensing, it changed its hue to that of dark smoke, and came back in a constant shower, which soon wetted us to the skin. This shower falls chiefly on the opposite side of the fissure, and, a few yards back from the lip, there stands a straight hedge of evergreen trees, the leaves of which are always wet. From their roots a number of little rills run back into the gulf; but, as they flow down the steep wall there, the column of vapour, in its ascent, licks them up clean off the rock, and away they mount again. They are constantly running down, but never reach the bottom.

"I saw the falls at low water, and the columns of vapour, when five or six miles distant. When the river is full, or in flood, the columns, it is said, can be seen ten miles off, and the sound is quite distinct somewhat beyond Kalai, or about an equal distance. No one can then go to the island in the middle."

THE "BOILING POT." HERE ALL THE WATER OF THE FALLS IS CONCENTRATED IN ITS ESCAPE

The "Trans-continental," or "Cape to Cairo" Railway, which is already running as far as Bulawayo, and is practically completed for 100 miles beyond,



BY PERMISSION OF THE BRITISH SOUTH AFRICA CO.

MAP OF RHODESIA, SOUTH AFRICA, WITH SPECIAL REFERENCE TO VICTORIA FALLS AND THE SURROUNDING AREAS LIKELY TO BE SUPPLIED WITH ELECTRIC POWER FROM THEM

will probably reach the falls several months before the close of 1903, when the survey and preliminary works for a great installation of electric power plant will commence.

The accompanying illustrations of the various portions of the Victoria Falls will, in conjunction with the two maps which show the comparative widths of the Niagara and Victoria Falls, serve to give some idea of their magnitude. In the Niagara River there are two falls, the American Fall, and the Canadian, or Horse-Shoe, Fall, separated by Goat Island, the entire width being about half a mile. The total height is from about 158 to 167 feet, and the estimated average horse-power running to waste is 7,000,000.

In the case of Victoria Falls there are three islands, the centre one known as Livingstone Island, as it was here that the doctor planted a number of fruit trees, all of which were destroyed by the hippopotami. The entire width is about a mile, the height of the falls is from 400 to 420 feet, and when the river is in flood it is estimated that the vol-

ume of water is about double that of Niagara, giving about 35,000,000 H. P. as running to waste. During the dry season this is much reduced; but, even in the driest years, the volume passing over the lip is very large. One of the most remarkable features of the place is the gorge, which is entirely cut out of basalt, and runs zigzagging for many miles. Of this an excellent photographic reproduction is given on page 684.

The "Cape to Cairo" Railway will traverse the peninsula of rock immediately in front of the falls, and will cross the gorge by the bridge shown on page 696. The clear span of the arch of this bridge will be 500 feet, and the height, 400 feet above the river, in consequence of which no staging nor scaffolding can be employed in its erection. The proposed bridge is intended to be built out from each bank of the ravine, on the cantilever principle, until the steelwork of the arch meets in the centre. The width of the bridge will be sufficient for a double line of railway, and on a lower level provision will be made for the addition at a future date of a roadway for vehicles and pedestrians, thus affording a much-needed communication across the Zambesi.

The actual position of the town, which will inevitably spring up adjacent to the falls, has not yet been definitely decided; but it will probably be on the south side, and here will be built a suitable hotel, for the accommodation of traders and travellers, and to which visitors will, doubtless, flock from all parts of the world.

Quite recently the falls were visited by Sir Charles Metcalfe, Bart., who, with Sir Douglas Fox, is one of the consulting engineers to the British South Africa (Chartered) Company. Upon his return from the falls he communicated his impression of their possibilities to the late Right Hon. Cecil Rhodes, and the latter, with his usual receptivity

A PORTION OF THE GORGE BELOW THE FALLS

ANOTHER VIEW OF THE GORGE, ABOUT A MILE BELOW THE FALLS

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of large ideas, at once took action in the matter, and initiated the arrangements now in progress for utilising the power.

Before describing generally what is intended to be done to utilise the power by harnessing some portion of the falls, it will be desirable to ascertain what has already been accomplished in other places up to the most recent date. Electrical science is developing with such giant strides that even the last two years have produced unlooked-for results.

The two great questions which have to be answered are, first, to what distance can electrical energy be transmitted with practical and economical results; and second, what is the limit of voltage which can be adopted in various climates?

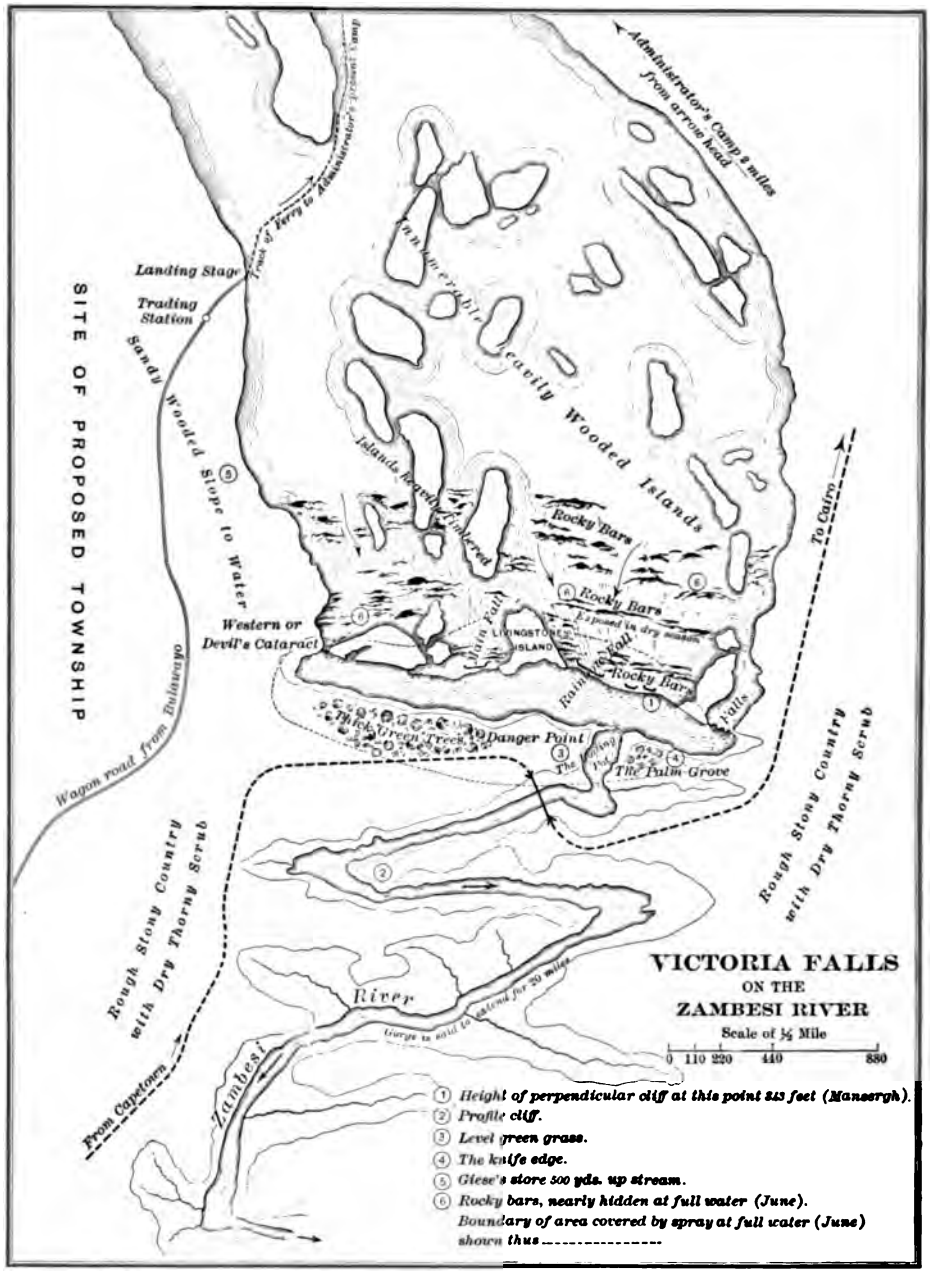
In the United States, the application of water-power has been largely developed. The works of the Niagara Falls Power Company at present provide 50,000 H. P., upon which practically 500,000 people are dependent in Niagara, Lockport, Tonawanda, and Buffalo. The current, generated at 2200 volts, is transmitted at a pressure of 22,000 volts by overhead transmission lines to a point thirty-five miles distant, the loss in transmission, including step-up and step-down transformers, being about 12½ per cent.; but for local distribution, where underground cables are requisite, 10,000 volts are the maximum pressure at present adopted. This installation is now being increased to secure a total of 110,000 H. P.

When one considers the various purposes to which electric power is applied in the Niagara district, it is at once apparent that in a highly mineralised country, such as Rhodesia, the applications of electricity will, in due time, be almost numberless. At present the power of Niagara is used for the following purposes, amongst others, in many of which the electric furnace plays an important part:—The manufacture of aluminium; operation of water-works, alkali works, and carborundum and graphite works; acetyvone manufacture; electric lighting; reduction of ores; manufacture of flax fibre; electric railways; lead reduction; in operating a natural food factory; a hook and eye factory; carbide works; chemical works; emery-wheel factory; switch and crossing works; paper factory; pulp factory; and biscuit factory. The possible applications are capable of almost unlimited extension.

It may be well to point out wherein lies the great advantage of the electric furnace. In an ordinary furnace supplied with coal, coke, or wood fuel the heat depends upon an ample supply of air, with its component of 23 per cent. of oxygen. The more air, the fiercer the heat; but, in the electric furnace, neither oxygen nor air is required to produce the highest temperatures, such as are unattainable by any other known means, and consequently the furnace, which is closed so that air cannot enter, may be supplied with any combustible matter found to be most eligible for the particular process in hand. Perhaps an exception should be made of "thermite," in which aluminium is used for reducing, in a simple and expeditious manner, the most refractory ores of such metals as chromium, cobalt, and tungsten, provided that they are in the forms of oxides.

The most familiar instance of an electric furnace is the ordinary electric incandescent lamp. In this a fine filament of charcoal is heated to a glowing incandescence by the electric current. Were it exposed to air, it would instantly be consumed; but, being in a high vacuum, it cannot burn. In like manner the most inflammable material, phosphorus, which will burst into flame when exposed to a temperature of only 55° C., can be reduced and its vapour can then be raised to a temperature of 1500° to 2000° C. without combustion, by keeping the furnace supplied with carbon, so that there is nothing with which it can combine.

It is probable that the highest temperature attainable from fuel is about 2000° C., whereas the theoretical temperature available in the electric furnace is about 18,000° C. Chemical reactions at high temperatures have only within the last ten years been practically attained, and an unlimited field for investigation and for employment is


SITE OF PROPOSED TOWNSHIP
Landing Stage
Trading Station
Sandy Wooded Slope to Water
Western or Devil's Cataract
Wagon road from Bulawayo
Rough Stony Country with Dry Thorny Scrub
From Capetown
Zambesi
River
Admiralty's Camp 2 miles from arrow head
Impenetrable Heavily Wooded Islands
To Cairo
Rocky Bars
Rocky Bars
Rocky Bars
Rainbow Fall
Falls
Danger Point
The Palm Grove
Rough Stony Country with Dry Thorny Scrub
VICTORIA FALLS
ON THE
ZAMBESI RIVER
Scale of ½ Mile
0 110 220 440 880
(1) Height of perpendicular cliff at this point 355 feet (Manserghi).
(2) Profile cliff.
(3) Level green grass.
(4) The knife edge.
(5) Giese's store 500 yds. up stream.
(6) Rocky bars, nearly hidden at full water (June).
Boundary of area covered by spray at full water (June) shown thus

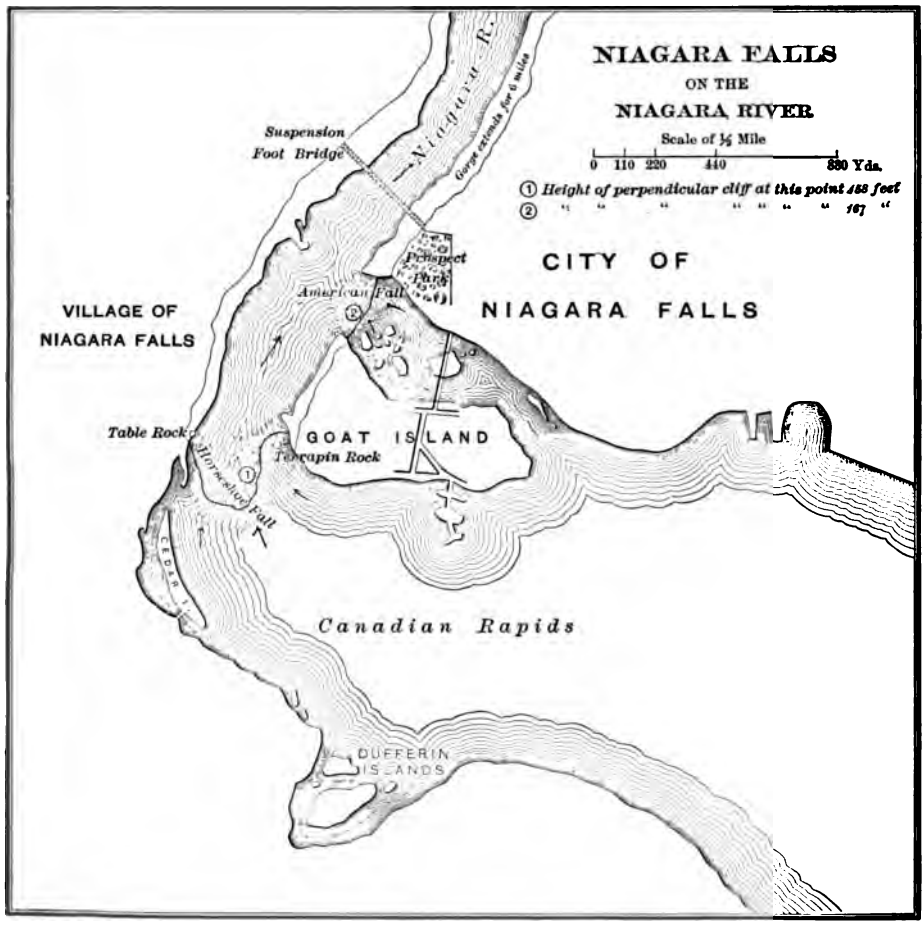
thrown open by the development of the science of electro-chemistry. Take, for instance, the manufacture of carbide of calcium,—a product which was discovered quite by accident; or of carborundum, for obtaining which three materials, each beginning with the letter S, namely, sand, sawdust and salt, are mixed in certain proportions and placed in a suitable furnace. After passing the Niagara current through the charge for fifteen hours, the product is a mass of

crystals of metallic lustre and of beautiful form, with a degree of hardness ranking next to the diamond. The material is used as an abrasive, much in the same way as is emery.

Electrical energy can also be applied with great advantage to pumping water out of mines, ventilating underground workings, hauling of waggons from the deep levels, driving drills,—in fact, doing a wide variety of work. Hitherto in deep mines, in which water has been encountered in quantity, the shaft is largely occupied by the heavy pumping rods and gear, which machinery not only encumbers the available space, but also is wasteful, because of the reciprocating movement of the various parts. Since the introduction of the admirable system of centrifugal high-lift pumps the shafts where they have been adopted have been cleared of pumping machinery, the only remaining parts being the necessary rising main, and an electric cable.

The silver mines of Horcajo, in Spain, have gathered round them a population of 5000 people. The depth at present is 1280 feet, which is being increased about 18 feet a year, the total future depth being placed at 1640 feet. The pumping is done by high-speed, compounded, centrifugal pumps, driven electrically. Each pump, on an average, lifts through about 400 feet, and this arrangement has solved the important problem of how the mine was to be unwatered.

Formerly, powerful Cornish pumping engines had been fixed at great expense,



VICTORIA FALLS ON THE ZAMBESI RIVER, SOUTH AFRICA. HEIGHT, 343 FEET,—MORE THAN DOUBLE THE HEIGHT OF NIAGARA FALLS AND DOUBLE THE VOLUME WHEN IN FLOOD

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and had proved both costly and unsatisfactory in working; but, by the adoption of centrifugal pumps, all spears and rods have been dispensed with, all reciprocating motion has been avoided, and the ascending column of water is kept in constant motion, thus avoiding the serious hydraulic blows which formerly burst the strongest pipe.

At a large colliery in South Durham spear rod pumps, lifting 1000 gallons per minute against a head of 400 feet, have been removed, and three-throw pumps, electrically driven, have been substituted, effecting a saving of £1500 a year. In Northumberland and Scotland similar changes have been effected, with economies of £1800 and £3000 a year, respectively.

For hauling and winding engines the advantages of electric power are great, obviating the necessity for engines, boilers, chimneys, and fuel. Electrically-driven fans for ventilation, and electric pumps, can be placed in the most remote parts of a mine. The advantages will specially be appreciated by all who have had practical experience of mining, and who know the serious problem of raising water, or of extracting vitiated air from the dip levels of deep mines.

In a certain mine, in a far-off dip level, an electric pump is fixed, which is actuated from the power house at the surface; there a telephone is attached, by which the engineer in the power house can ascertain whether the pump is at work and acting properly without the necessity of a man being in constant attendance.

But whilst upon this subject of mining, it is desirable to call attention to the very serious results occurring to the employees of a mine, from the dust produced by the drills used in driving the advance galleries and in the stopes. In the copper mines of Cornwall and in the gold mines of Johannesburg the gravest results are produced upon the men; hence the reason for so many miners being consumptive. It is a well-known fact that the life of a miner in charge of an advance heading is short; consequently the pay is high, and it is not uncommon for a foreman in charge to be paid £100 a month. The writer has personal knowledge of one case in which a gang of sixteen Cornish miners, fine, stalwart fellows, in charge of a certain heading or driftway, all died from consumption within a comparatively short time. Such occurrences naturally make white men reluctant to enter the mines, even if highly paid; and this accentuates the labour problem on the Rand.

The Chamber of Mines at Johannesburg have offered three prizes, one of £500 and a gold medal, one of £250, and one of £100, for the best device for ridding the mines of dust, and thus reducing the present heavy loss of life from "miners' phthisis." Hitherto a remedy for this trouble has not been forthcoming, but this excuse can no longer be pleaded. In the Simplon tunnel, in course of construction through the Alps, the length of which is twelve and one-half miles, the Brandt hydraulic drill is working with the greatest success; no dust is produced in the advance galleries, splendid ventilation is provided, and the rate of progress has completely beaten the world's record. Headings, 10 feet in width and 8 feet in height, are driven through gneiss, and other very hard rock, at a speed of over 700 feet a month, and in one case of 770 feet, without injury to health or life and much diminished cost of driving.

A well-known tunnel contractor in Scotland called upon the writer to ask if there were not some mistake in the above figures. Had not a decimal point been left out? He would consider 70 to 77 feet a month good work. He could not believe that ten times this rate of progress could be attained until the official returns were shown to him.

One objection has been raised to the introduction of this drill into the gold mines of Johannesburg, namely, the comparative scarcity of water; but as the water can be used over and over again, this objection is of small importance. This drill is actuated by high-pressure water,—1500 pounds to the inch,—and is kept up to its work with a pressure of 10 tons; all the waste water is discharged through the drill up

ANOTHER VIEW OF THE FALLS, SHOWING LIVINGSTONE ISLAND IN THE MIDDLE

to its cutting points, thus keeping it cool and washing out the débris. If pumps are required, they can be driven either by air or electric current, or, should the mine be of great depth, the hydrostatic head of water in the supply pipe would give the required pressure. The waste water would be collected in an underground tank and raised to the surface by electric pumps, and could thus be used over and over again.

In the case of the Cauvery Falls, in Mysore, India,* an electric power installation has been provided to furnish power for the gold fields, and the current will be transmitted a distance of ninety-three miles.

The voltage at the generator is 2200 volts, and the line voltage is 30,000. Owing to the valley of the river being malarious, the switchboard is placed on high ground 1000 feet away from the power house. There are seven generators of 750 KW each, with revolving fields and stationary armatures. There are fifteen step-up transformers of 375 KW each, and fifteen step-down transformers each of 330 KW.

The transmission line consists of two parallel lines of poles 60 feet apart. The poles consist of steel sockets 13 feet in height, which carry timber posts 17 feet in height and 7 inches square. Each pole carries three No. 0 B. & S. gauge bare copper wires, the insulators being arranged so as to form an equilateral triangle with 40-inch sides. The poles are approximately 130 feet apart along the line, but in at least one river crossing a span of 525 feet is required, and stranded silicon-bronze cable of high tensile strength is there used. Similar wire is used wherever railways or telegraph lines are crossed.

Some of the advantages of a double-pole line are, less likelihood of complete interruption of the circuit, due to the improbability of both lines giving out at the same time, and also the possibility of effecting repairs on one line while the other is delivering power.

The electrical transmission of the Missouri River Power Company, in Montana, in the United States, is well worthy of notice. With an average head of water of 30 feet, about 10,000 H. P. are available. Machinery for about 4000 H. P. was, in the first instance, installed, consisting of four 750 KW, 550-volt, two-phase generators. The current is raised from 550 volts to 10,000 volts, and sent to Helena, twenty miles from the power house, and East Helena, fourteen miles distant, where it is stepped down for consumption. In 1900 six additional 750-KW generators were added for the purpose of supplying power to Butte, Montana, sixty-five miles away. The transmission line passes over the mountains at an altitude of 3300 feet above the power station, and consists of three lines of posts, 50 feet apart, the distance between the posts being 110 feet.

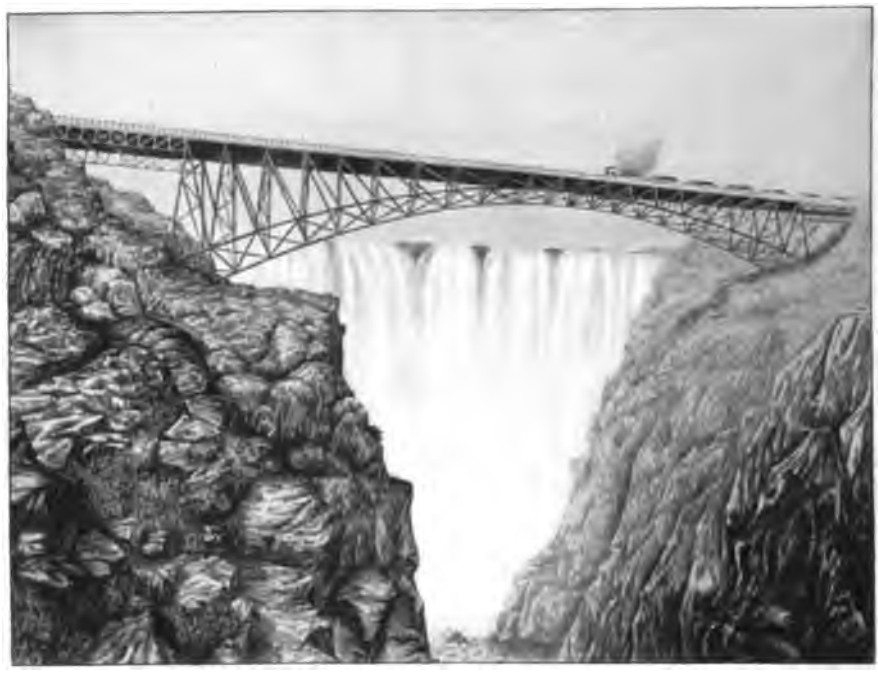
The wires are placed in the form of an equilateral triangle, each side being 78 inches long. The insulators are fixed on oak pins boiled in paraffine. The current, as already stated, is generated at 550 volts, but in this case is stepped up at the power house to 50,000. At Butte the step-down transformer reduces the voltage to 2200.

One of the most remarkable examples of electric long-distance transmission is in the State of Washington,—the Snoqualmie Falls plant. The transmission line is forty-four miles long, carrying current at 30,000 volts, and in order to protect the generators from the spray of the falls the power house is a cavern cut out of the solid rock 250 feet below the surface, in which there are six generators of 1500 KW each.

The Bay Counties Power Company utilise the Yuba Falls, at Colgate, California, in a power house containing three units of 3000 H. P. and four of 1500 H. P., and deliver current at Oakland, 152 miles distant; thence it is passed along the transmission lines of the Standard Electric Company to San Francisco,—a further distance of 70 miles,—making 222 miles in all.

For nearly twelve months power has been delivered from Colgate to Stockton, a distance of 216 miles, and, dur-

* A comprehensive account of the Cauvery Falls plant appeared in this magazine for January, 1903.



THE PROPOSED BRIDGE OVER THE ZAMBESI RIVER AT VICTORIA FALLS, ON THE RHODESIA RAILWAY. SPAN, 500 FEET; HEIGHT, ABOVE WATER 400 FEET

ing the month of August last, in order to avoid a "shut-down" at Sacramento, 1000 KW were transmitted 270 miles, the longest distance yet attained. The volt meters at Sacramento did not show anything abnormal, nor did the operators there know anything as to whence this power was being derived until the operation was over.

The lines are all laid out for a 10 per cent. loss, transmitting 12,000 H. P. The voltage is at present 40,000, and is intended to be raised shortly to 50,000; but, in the opinion of the general superintendent of the line, Mr. L. M. Hancock, there is no reason why 60,000 to 80,000 volts should not be employed, if the line be properly designed, every insulator being tested up to 120,000 volts.

The latest results attained in America enable the following average percentages of efficiency and loss to be ascertained, assuming a power of 10,000 KW, or 13,400 H. P., delivered at a point 300 miles distant:—

	KW.
Step-down Transformers, 98 per cent. efficiency	10,200
Transmission Line, 70 per cent. efficiency	14,600
Step-up Transformers, 98 per cent. efficiency	14,900
Generators, 96 per cent. efficiency	15,500
Water Turbines, 80 per cent. efficiency	19,400
Water Mains from falls, 90 per cent. efficiency	21,600

This represents a delivery to the consumer of 46 per cent. of the actual power of the water at the falls.

Having thus briefly reviewed what has been done in some other parts of the world in the way of utilising water-power, we will now consider the question of possible electrical development from the Victoria Falls. In a new country, like Rhodesia, everything is required for what is practically a new country, and in connection with its extensive gold deposits there are two essentials, cyanide of potassium and quicksilver. Of both of these large quantities are requisite. Although quicksilver has thus far not been discovered in quantity, samples of cinnabar, from which it is obtained, have been brought in by the natives, and it is probable that both the above agents can be produced on the spot.

Gold mines to the southeast, the coal

mines of Wankie, and the important copper deposits in Barotse Land, which are believed likely to prove among the greatest in the world, would all require power to a very large extent. Chemical and metallurgical industries will be attracted, as they have been at Niagara, and, if alluvial gold deposits exist, as reported, in the vicinity of the falls, they might be cheaply worked by "hydraulicking," that is, washing down the beds by powerful water jets supplied by electrically-driven pumps.

Water would also be required for irrigation, and ploughing, sawing timber, and all kinds of agricultural work could be carried on by electrically transmitted power. The great need for manufacturing on the spot all the various products which can be obtained by electrical energy is at once apparent when it is remembered that, at the present time, these have to be obtained from America and elsewhere, and transported thousands of miles, by sea and land, to the numerous points of consumption within a moderate distance of the Victoria Falls. In other words, both the necessary materials and the power are at the very doors of the Rhodesian population, and need only to be rightly developed.

The power house at the Zambesi would be placed on a benching in the second zigzag below the cascade, and would be supplied with water by steel tubes from the fall. Any amount of power required could be obtained, and an available head of at least 250 feet could be utilised. Each pipe or tube, 8 feet in diameter, would drive a turbine and generator necessary for 5000 horsepower, and it would probably be found desirable to lay down the plant in units of this magnitude. The ultimate size of the power house would have to be determined by the demand for electricity in the neighbourhood.

The question of voltage would depend much upon climatic conditions, and also upon the output and the distance to which power would have to be transmitted. At high voltages the air ceases to be a good insulator, and when moisture is present, sparking into the atmosphere takes place, and a large amount of electricity passes through the air from one wire to another. Transformers and insulators can be designed for much higher voltages than are now adopted, but at present the limit seems to be that at which an uncovered copper conductor will retain the current.

The rapid advance which is being made in electric transmission work enables distances to be satisfactorily dealt with which were considered impracticable four or five years ago. Many of the difficulties which were anticipated have never arisen, and many interesting and scientific observations have been made, such, for instance, as the tendency of high-tension current to keep the porcelain and glass insulators dry in moist climates, and even during rain. It is only a question of conscientious work and careful design to make a long-distance transmission, even of 300 miles, within the near future a successful commercial undertaking.

THE IRON ORE MINES OF BISCAY

By Bennett H. Brough

THE ARMS OF BISCAY

THE ancient lordship of Biscay is, with one exception, the smallest province in Spain. Its laws still differ from those of the rest of Spain, being the relics of the ancient prerogative of self-government. The hardy Basque race inhabiting the province are, like many mountaineers, keen and self-reliant, vigorous in public life, and full of energy in developing the resources at their disposal. These qualities, combined with the characteristic Spanish virtues of pride, patience, self-control and true courtesy, the outcome of respect for another's individuality, produce a singularly superior and interesting type. Biscay enjoys prosperity unknown in other parts of the peninsula, although its soil is so poor that only a very small portion repays cultivation. This prosperity is due to the vigorous development of the mining industry brought about by the enormous demand for pure iron ores consequent on Bessemer's invention.

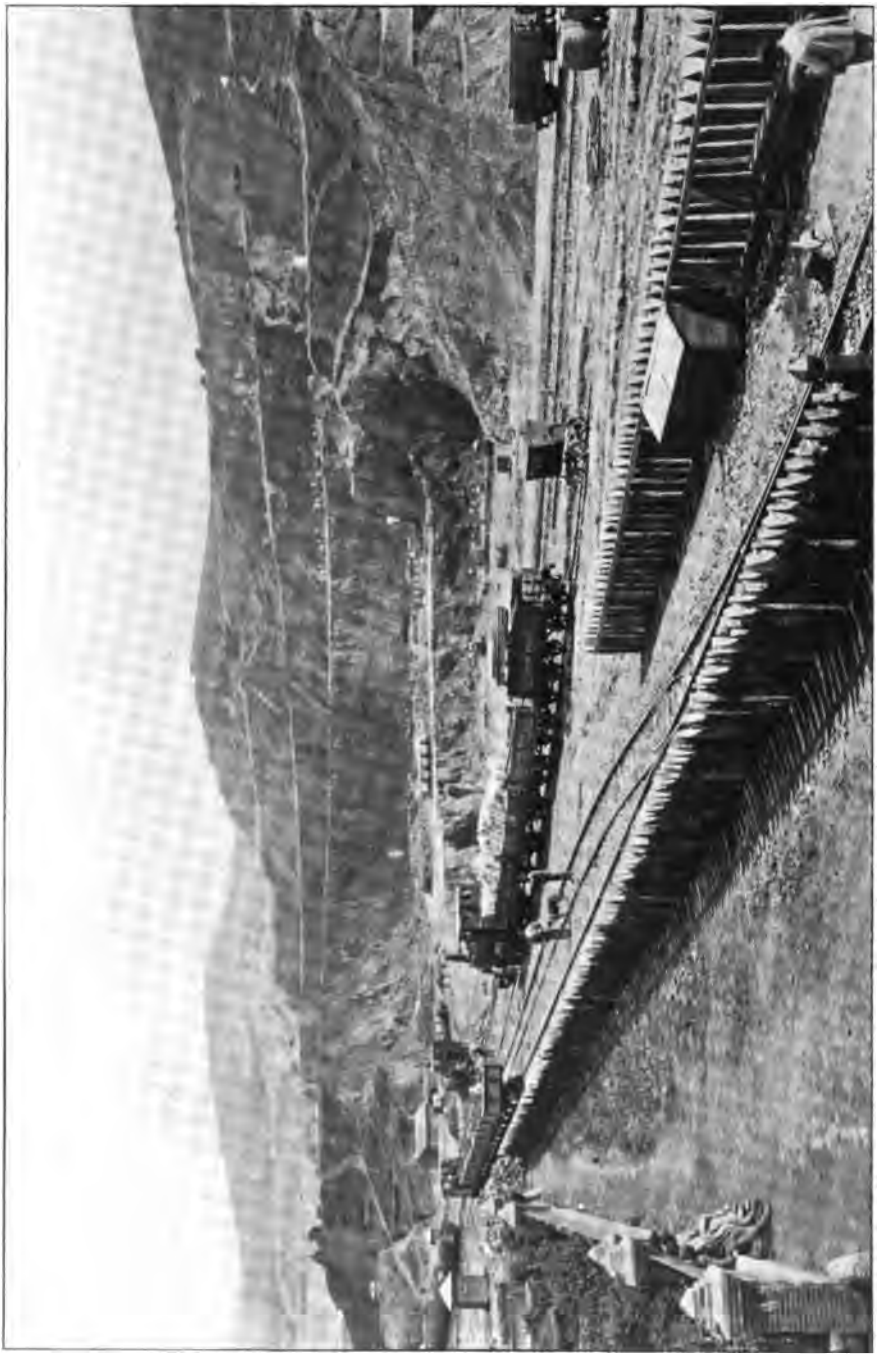
Spain has been richly endowed with mineral wealth of all kinds. Biscay is, however, rich only in iron. The iron ore deposits were known in the earliest times. The Somorrostro deposit, which is the only one that has been worked continuously up to the present time, was mentioned by Pliny 1850 years ago. "In that part of the Cantabrian coast," he writes, "which is washed by the ocean, there rises a high and steep mountain, which, incredible as it may seem, is composed entirely of iron."

It is not known when the iron ores of Biscay were first used, but as far back as the tenth century the soft ore of Somorrostro was shipped in the Bilbao River to Spanish and French ports. In the sixteenth century it was exported even to England, and the old fame of the iron and steel made from Bilbao ores is attested by the term Bilbo, commonly used by Elizabethan writers for a rapier. In the "Merry Wives of Windsor" Falstaff testifies to the flexibility of such rapiers by speaking of being "compassed, like a good bilbo, in the circumference of a peck, hilt to point, heel to head."

Much has been written about the mines of Biscay. In Spanish there are the memoirs of Don Fausto Elhuyar, 1783; of Don Rafael Amar de la Torre, 1844; of Don Lucas Aldana, 1851; of Don Ignacio Goenaga, 1862; of Don Ramon Adan de Yarza, 1877 and 1892; and of Don Ignacio de Echeverria and Don Federico Grijelmo, 1900. In English the most important monograph was that prepared by the late Mr. William Gill, general manager of the Orconera Company, when the Iron and Steel Institute visited Bilbao in 1896. Important memoirs have also been published by French, German, Belgian, and Italian experts.

These valuable works have helped much towards the extraordinary development of the iron ore industry. Improved methods of transport have made this development possible. Railways have been constructed for the transport of the ore, one of which, built by the provincial government, has carried more than 30,000,000 tons, or about one-third of total output exported, almost exclusively from the Triano region, which has produced from 1860 to 1901 the enormous total of a hundred million tons of ore.

The impetus given by the brilliant results obtained at Somorrostro has led to the working of mines throughout the



THE ORCONERA IRON COMPANY'S MINES AT MATAMOROS. A VIEW AT ARBOLEDA STATION OF THE MATAMOROS BRANCH RAILWAY

THE CONCHA MINE OF THE

provinces. It is thought, too, that the ore from this zone will soon be exhausted, as well as that from Galdames, especially if operations are continued on a large scale, for in 1901 the output was nearly 5,000,000 tons, to which total the Orconera Company contributed more than 1,000,000 tons, and the Franco-Belge Company more than 500,000 tons. The geological structure of Biscay is simple. The north coast of Spain is composed chiefly of rocks of cretaceous age. The iron ore occurs in beds that follow the configuration of the limestones and sandstones in which they lie. The area within which the more important beds occur measures fifteen miles in length and three and one-half miles in width.

The ore raised in this area is known as Bilbao ore, and is mostly shipped at various places on the Bilbao River. Four classes of ore are distinguished:—

1. Vena, a soft, purple, compact, and often powdery red hæmatite.

2. Campanil, a compact and crystalline red hæmatite, often accompanied by rhombohedra of carbonate of lime.

3. Rubio, a brown hæmatite, usually mixed with silicious material; and

4. Carbonato, a grey granular and silicious, or a creamy-white laminated and crystalline spathic iron ore.

Vena is the purest of these ores, and was in former times the only one used for the local Catalan forges. Campanil, on account of its freedom from phosphorus, is the most valuable ore; but it is now nearly exhausted. Rubio, on the other hand, is the ore that is met with in largest quantities. It is, however, often associated with iron pyrites, which renders careful selection necessary. Unlike campanil, it is usually found uncovered. The writer remembers seeing in 1888 some bold outcrops of this ore. With the extension of mining operation this picturesque feature of the landscape had entirely disappeared when he revisited the district in 1896.

ORCONERA IRON ORE CO., LTD.

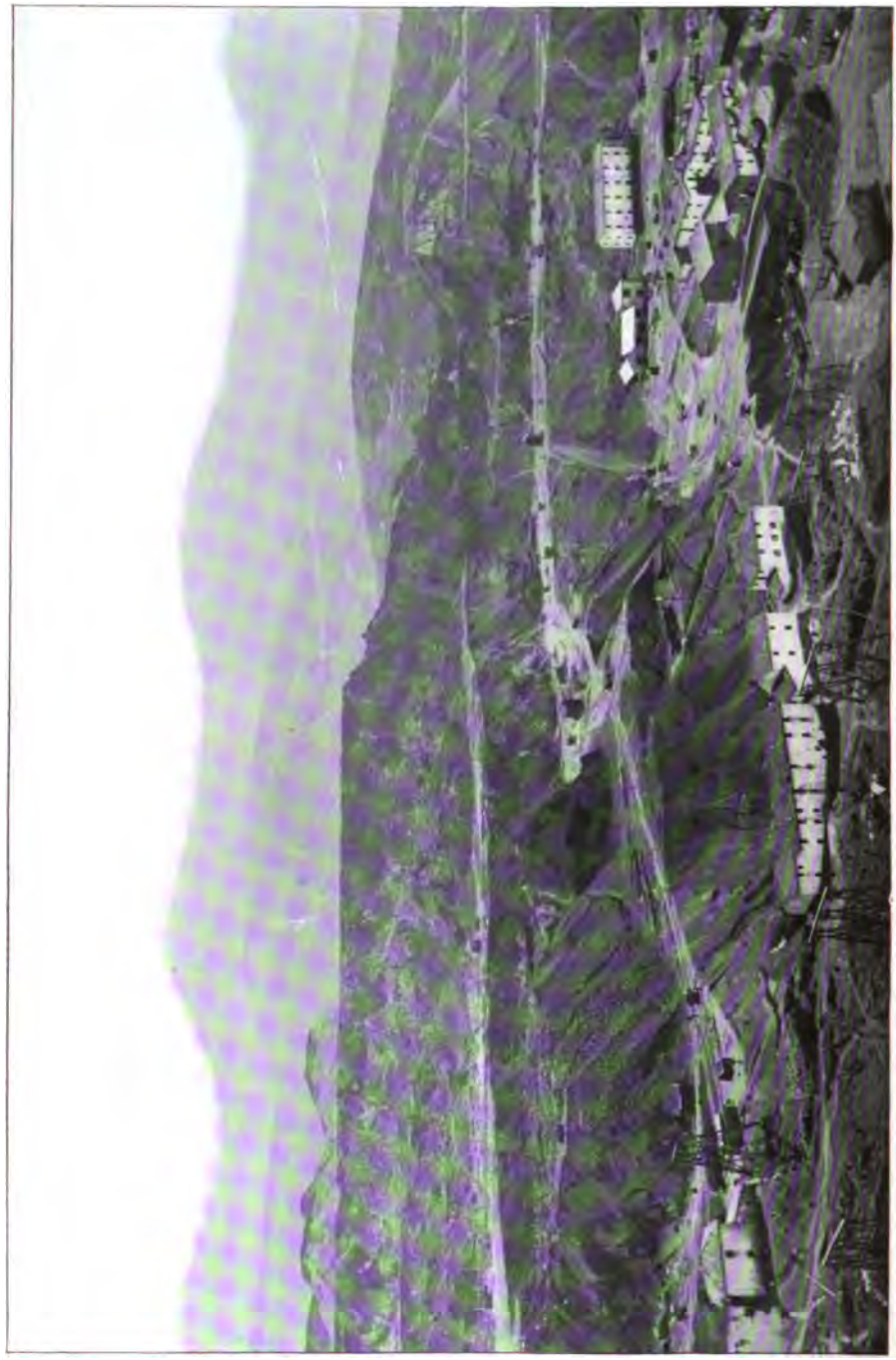
Carbonato is usually found below the other ores, and, after calcination, it finds a ready sale. Large masses of this ore occur at various points, notably at the Concha mine. The diagrams on page 703 show the mode of occurrence of the ore, 1 indicating sandstone, 2 hard limestone, 3 argillaceous limestone, and 5 iron ore.

Don Ramon Adan de Yarza, whose papers furnish the most trustworthy information regarding the geology of these deposits, is of opinion that they were formed by hydro-thermal action. Springs, charged with ferrous carbonate, dissolved by reason of an excess of carbonic acid, acted on the limestone beds; and as the carbonate of lime is more soluble in water saturated with carbonic acid than the ferrous carbonate, it has been replaced by the latter, which, in its turn, has been changed into hæmatite by a subsequent loss of carbonic acid and absorption of oxygen.

Seven districts are distinguished. The principal, or Somorrostro, district, containing two huge beds of iron ore,—that of Triano on the west, and that of Matamoros on the east,—yields the largest quantity of ore, about 3,500,000 tons annually. In these cases spathic iron ore overlies the limestone at the deepest points, while in the higher portions red hæmatite is deposited immediately on the limestone. The brown hæmatite lying above, in both cases, encloses numerous crystals of spathic ore. The ore is worked by quarrying.

The ore mass at Monte Triano has an irregular shape, and extends for a length of 3080 yards, while its thickness increases from a few yards up to 30 yards. The Matamoros mass includes the Orconera, Amistosa, and other important mines. It has a length of 1¼ miles and a maximum width of 800 yards. The districts of Galdames, Sopuerta, Ollargan, Abondo, Alonsotegui, and Gueñes also yield large quantities of ore.

Analyses of ore from the Orconera



THE AMISTOSA MINE AT MATAMOROS

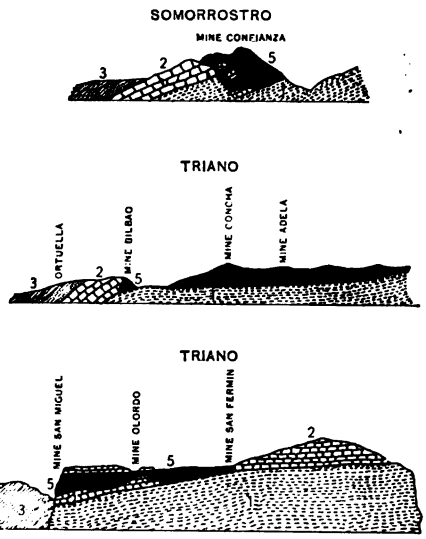
Company's mines show that vena contains 55.97 per cent. of iron; campanil, 54.62 per cent.; rubio, 54.80 per cent.; grey spathic ore, 43.70 per cent.; white spathic ore, 45.73 per cent.; and calcined spathic ore, 62.85 per cent.

The ore is worked open-cast, with one or two exceptions, in consecutive lifts. Rock boring is done by hand, the bore holes being usually 15 or 20 feet deep. The best results are obtained when a foot shot and a back shot can be fired in quick succession. In this way 6000 tons were brought down at the Orconera mine with two 16-foot holes. The firing takes place throughout the district at prescribed hours, from 8 to 8.30 A. M., 12 to 1 P. M., and 4 to 4.30 P. M., signals being given by a bugler. Dynamite is the explosive mostly used. About 12,000 workmen were employed last year at the mines. the annual output per miner being about 500 tons.

For many years the carbonate of iron raised was of no value. Attempts were consequently made to calcine it. Small kilns were built by the Franco-Belge Company in 1881 and by Mr. J. MacLennan in 1882. The Luchana Mining Company was, however, the first to apply calcination on a large scale. The kiln built in 1889 had an iron shell, and was 38 feet high and 20 feet in internal diameter. Its output was 180 tons a day. In 1892 the Franco-Belge Company and Messrs. J. B. Rochet & Co. built fire-brick kilns that gave excellent results, and the initiative was soon followed by others, with the result that there are at the present time thirty-three kilns at work in the district, with a total daily output of 1941 tons.

The remarkably successful results obtained with washing iron ore in the province of Santander has led to its introduction in Biscay. The first attempt was made in 1891 at the Marta mine. Excellent results were obtained, and the method has consequently been largely adopted. At the present time there are in operation sixteen washing plants with forty-nine trommels, in which are treated the output of twenty-six mines, the total daily capacity being 2590 tons.

One of the most interesting features of the Bilbao district is the variety of haulage systems employed for transporting the ore to the railways and to the port. Haulage by bullock cart has long since died out. In addition to the inclined planes used at most of the mines, there are numerous wire ropeways of the Pohlig, Bleichert, and Hodgson types, and three endless chains, the first of which was installed

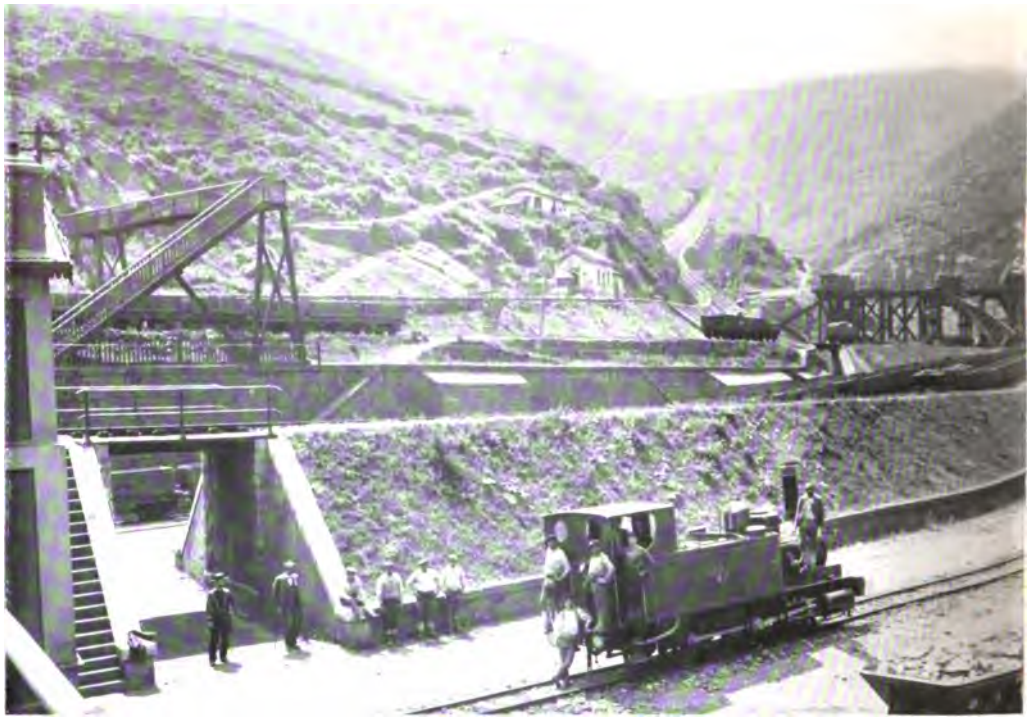


SECTIONS OF THE BILBAO DEPOSITS

in 1883 by the Franco-Belge Company from its mines to the Ortuella Railway terminus; the second was installed in the Galdames district; and the third for carrying the ores from Arraiz.

Moreover, the extensive area over which the workings spread has necessitated the establishment of branch railways. Of these the railways carrying the output of the vast mines of the Orconera Company are the most notable. The different railways belonging to this company transport daily 3000 tons of ore and 2000 tons of waste. The Orconera Company owns the most important incline in the district. It is 1200 yards in length, and the maximum gradient is 21 per cent.

The Franco-Belge Company also has important inclined planes at the Concha



A VIEW AT ORCONERA STATION LOOKING

mines; but owing to the situation of other mines belonging to the company and to the nature of the ground, a separate haulage scheme had to be planned, and the endless chain was adopted. The difference of level of this line from the Sol mine to the Cadegal Railway terminus is 802 feet, and the maximum gradient 29.5 per cent. The daily capacity of the line exceeds 2000 tons.

Aerial wire ropeways are naturally largely used in this mountainous district. The first was constructed in 1875 by Mr. Stephens to transport ore from the Parcocha mine. The example was soon followed by the Orconera Company and by Messrs. J. B. Rochet & Co., and there are now fourteen wire ropeways in operation. These modern methods of transport have by no means displaced the use of barges. Indeed, last year the mines Malaespera, Silfide, Abandonada, San Luis, Begoña, Pequeña, and others transported more than 300,000 tons by barges from Achuri to the Deusto River. Since the introduction of mineral railways the operations of shipment have been constantly improved and have attained a high degree of perfection. It is now possible to load into ships 1000 to 2000 tons for each staith per day.

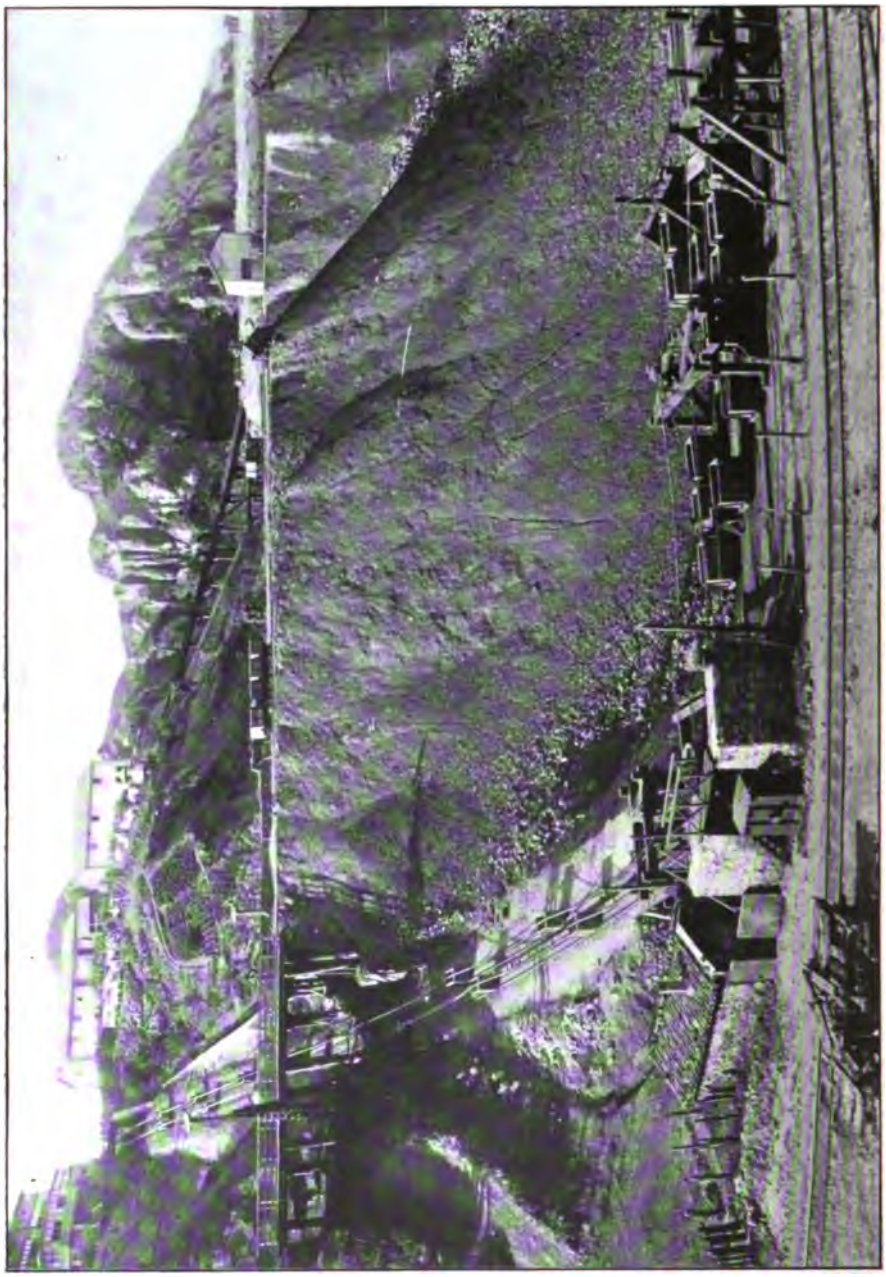
It has already been pointed out that iron ore mining in the province of Biscay dates from time immemorial. The output, however, never exceeded 5000 to 10,000 tons annually, or about a million tons per century. In the second half of the nineteenth century, thanks to Bessemer's great invention, the industry rapidly developed. From 1865 to 1870 capitalists and engineers from all parts of the world rushed to the ore fields of Triano to study and to exploit the

TOWARD THE ORCONERA INCLINE AND MATAMOROS

famous deposits of iron ore free from phosphorus,—the ideal raw material for the Bessemer process. In 1870 Don Carlos Aguirre acquired a concession to work the mines of Galdames. In 1871 the line of the Bilbao River & Cantabrian Railway Company, Ltd., was opened. In the same year the Luchana Mining Company was formed, under the auspices of the late Lord Armstrong and Messrs. Bolckow, Vaughan & Co., and soon afterwards the firm of Ibarra & Co., of Bilbao, brought about the formation of the two great undertakings,—the Orconera Iron Ore Company, Ltd., and the Société Franco-Belge des Mines de Somorrostro. The former, of which Sir David Dale is chairman, included the Dowlais Iron Company, the Consett Iron Company, and Fried. Krupp, and the latter the Société de Denain, the Société de Montataire and the Société Cockerill. Much of the prosperity of Biscay is due to the organisers of these great undertakings. But much is also due to eminent Biscayans. Men like Ibarra, Zubiria, Rochet, Larrinaga, Chavarri, Alzola, Churruca, Aznar, Sota and Lazurtegui have added hardly less to the prosperity of their country than Cortez and Pizarro, and their names, though not so world-famed, are deserving of equally lasting remembrance.

There are no official statistics of production available before 1860. The total output of the province of Biscay up to that date certainly did not exceed 15,000,000 tons. The iron ore output since 1860 is shown graphically in the accompanying diagram.

Up to the present time the Bilbao district has yielded about 115,000,000 tons of ore, and for many years past pessimistic estimates have been made of the

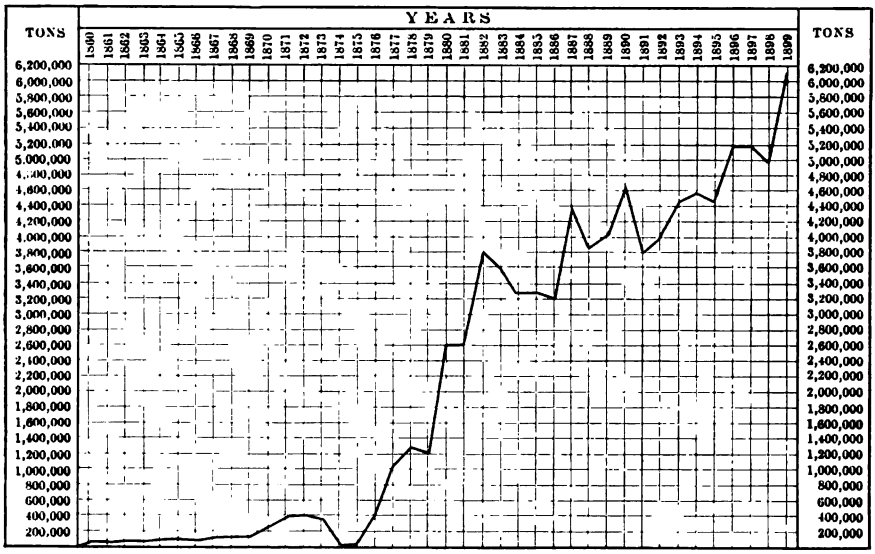


A SECTION OF THE ENDLESS CHAIN RAILWAY OF THE SOCIÉTÉ FRANCO-BELGE DES MINES DE HOMORROSTRO

quantity of ore remaining. Twenty years ago it was thought that by the year 1900 there would be no ore left. Nevertheless, in that year Bilbao exported nearly 5,000,000 tons of ore; and Don Julio de Lazurtegui, the most competent authority, estimated that there were still 57,770,000 tons available.

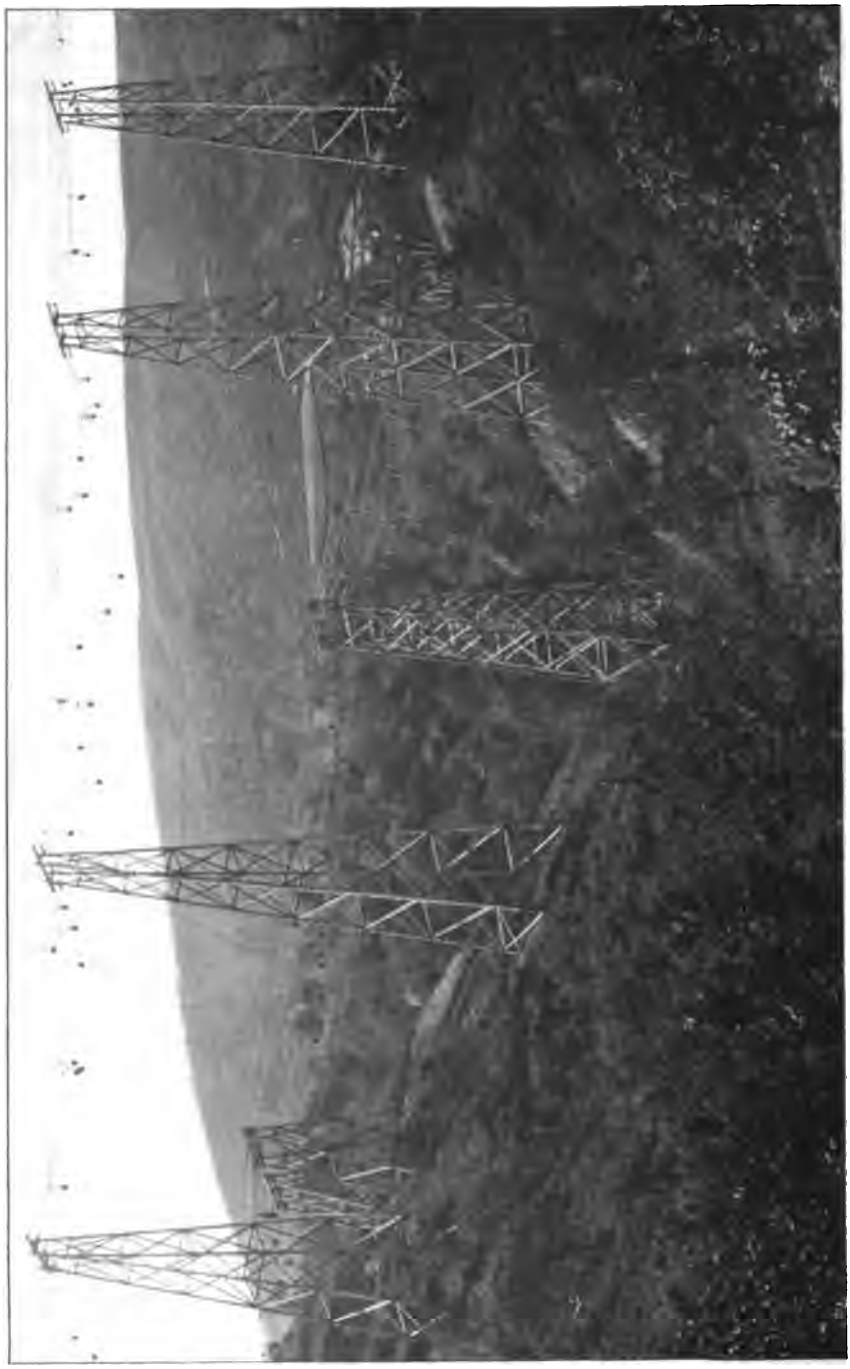
While it is true that the richest ores have been exhausted, and that more attention has to be paid to calcination and to the washing of ores of inferior quality to enable them to satisfy market requirements, there need certainly be no immediate apprehension of a Bilbao-ore famine. Far-seeing British ironmasters and Bilbao capitalists are, however, already making their arrangements for the time when substitutes for the Bilbao ores will have to be found. Happily there are still large fields of ore in Spain, almost untouched. In the province of Santander rich mines are being actively worked by the Orconera, San Salvador, Carmargo and other British companies. Messrs. W. Baird & Co., of Glasgow, have acquired the celebrated mines of the Cerro de Hierro in Seville and the deposit of Alquife in Granada has been acquired by other British firms. In Guipuzcoa, Murcia, and Almeria important deposits are being opened up by Bilbao capitalists. Indeed, Bilbao capitalists are throwing all their energies into the development of the country and the opening up of new ore deposits.

In 1901 in Bilbao 147 companies were floated with a capital of £19,291,550. Of these, 49, with a capital of £5,894,104, were mining undertakings, and 6, with a capital of £533,600, were shipping enterprises. The enterprise of the leading men in Bilbao has not failed to produce its effect in other regions of the peninsula. The iron ore deposits of Celra, Irun, and Lesaca, Villaodrid, Sierra de Bedar and Sierra Almenara are already productive, and the mines of Cala and of Sierra Menera will become so in a year or two. The product of all these mines will supply the British market.



IRON ORE PRODUCTION OF THE BILBAO MINES FROM 1860 TO 1899

For basic processes of steel making Spain possesses abundant ore supplies. The Vivero mines, in the province of Lugo, exported to the Rhine last year, the first year of the company's existence, 96,000 tons of ore containing 50 per cent. of iron and 1 per cent. of phosphorus. In the province of Leon the



A GROUP OF NINE LINES OF ROPEWAY AT BILBAO, ON THREE SETS OF POSTS, WITH A TOTAL CARRYING CAPACITY OF 2500 TONS A DAY. INSTALLED BY MESSRS. BULLIVANT & CO., LONDON

deposits of ore of this class are greater than the deposits of Biscay. Phosphoric ores are also being worked by Bilbao capital at Carreño, in the province of Oviedo. In short, no efforts are being spared to attract to Bilbao exports from the centre of Spain and imports from all parts of the world.

When the harbour works are completed, the port of Bilbao will be the finest on the Cantabrian coast, and if, as is proposed, a Bilbao exhibition be held to inaugurate officially the completion of the exterior port, it will serve to direct attention to the rising manufactures which will gradually supplant the mining industry as it wanes with the exhaustion of the iron ore deposits.

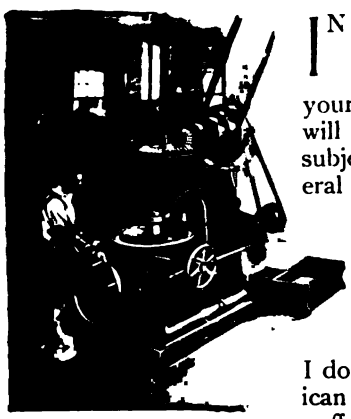
AMERICA'S SHORTCOMINGS

FROM A BRITISH WORKINGMAN'S POINT OF VIEW

By George N. Barnes

In presenting the following remarks, it may not be amiss to explain for the benefit of those not aware of the fact that Mr. Barnes is the secretary of the Amalgamated Society of Engineers,—Great Britain's strongest and most prominent trades union,—and was one of the twenty-three trades union delegates brought to the United States in the fall of 1902 by Mr. Alfred Mosely on an extended tour of inspection and observation of American engineering workshops, and labour systems and conditions in them. Mr. Mosely's own accounts of this enterprise were given in the January and February issues of this magazine of this year.

What Mr. Barnes wrote for publication here at the solicitation of the editor is based on the impressions gathered by him during that trip,—hastily gathered, of necessity,—with some evils unconsciously magnified out of true proportion. While, therefore, those familiar with the subject will not share his views without much qualification here and there, these undoubtedly are interesting and, in part, rest on a substratum of truth, as most Americans will probably admit cheerfully enough. Mr. Barnes' remarks, at any rate, represent honest expressions of opinions,—glimpses of America through a British workingman's eyes.—THE EDITOR.



IN venturing upon a few lines in response to your invitation, I will deal with the subject only in general terms. Let me say also that I am going to assume the rôle of "candid friend," feeling assured, as I do, that the American must be getting puffed up into an undue conceit of himself,—that is, if he has read recent magazine articles,—and that he will be all the better by having brought to his notice a few spots on America and Americanism which he may otherwise be disposed to ignore.

First, however, I desire to express admiration for the splendid system of education in America and for the no less admirable American patent laws. I believe that these two together,—the first by contributing to mental alertness on the part of directors of industry, and the second by encouragement given thereby to inventiveness,—have done more than all other causes to develop American industrialism. There is public provision of free education, not only in the elementary, but in the secondary and continuation schools as well, and, by that means, the technical schools are always supplied with an ample number of young men properly prepared to go right ahead. This compares very favourably with our system,—or want of system,—which gives no free tuition after the pupil reaches the age of fourteen, and which thus leaves the ground unprepared for technical instruction.

Again, in regard to the patent laws, I find that the American Government gives a patent for £7 which would here

cost £100, and they also sift the applications so as to give reasonable guarantee of novelty with the patent grant, whereas our people at the patent office practically give patents for fees, and regard inventors as sources of profit.

America, then, I freely admit, is ahead of us in these respects as much as in vastness of area, magnificence of natural manifestations, or stores of raw material.

It is when one considers America in its social aspects,—in the character of its governments or in the low standard which passes current in regard to quality of workmanship,—that America sinks in one's estimation. Its laws have led to the creation of monopolists who seem to be all-powerful, and who oppose any change in the direction of real freedom; its towns are uneven and slovenly, disfigured by sky-scrapers, grid-iron railways, and other contraptions of the "boodler" and company promoter; and its workshops turn out a lot of shoddy work at the expense of constant draughts upon the workers' health, efficiency, and permanent well-being. It is upon this last point only that I shall offer a few observations.

The American industrial system, on the whole, is directed to the greatest possible production of goods, and it is advocated and defended generally from that point of view. In regard to this two things may be said,—first, that it tends to produce a man of stunted growth and narrow view; and, second, that it tends to produce goods of inferior finish, because the workers' attention is too much directed to quantity, and too little to quality, of output.

Americans are drilled and specialised to a far greater extent than obtains in this country, and, as a result, America has, so far, been largely dependent upon other countries for the supply of mechanics. Everywhere I went in America I found persons of foreign extraction in positions as foremen and chief mechanics, and just as often I found the native-born Americans tending automatic tools or divided into gangs of specialists under the control of gang bosses whom we should here call "sweaters."

They have but few holidays, they work harder and longer per day, and their days are fewer as a result. The American worker is, in short, as a rule, a person of grubbing proclivities and dyspeptic complexion, who seems to have got beyond the point of taking his pleasures sadly by dispensing with them altogether.

As to the production of goods, the ill effects, qualitatively, are no less marked. I saw work being turned out as finished which would not pass muster in this country, but which is considered good enough for the American standard. The iron used is softer than that used here, and, therefore, less durable; less of it is used for any given purpose; and the workmanship put into it is far less painstaking than that of the British workman.

For proof of this the British traveller in America has but to keep his eyes open. He may note, for instance, the American locomotive, which he will find far different from that to which he has been accustomed. Instead of the trim, clean and nicely painted engines of the Midland or other of the English main roads, he will find a great, lumbering monster with leaky joints and asthmatic wheeziness, rough, black paint, and dirt-begrimed. Going into another field, if he compare the newspapers, he will find corresponding unfavourable features,—a few lines inverted in every other column, or words misspelt, and the reading matter of only a very commonplace character.

Observe, however, that I do not speak here of design, in which, especially where machine tools are concerned, the Americans are greatly in advance, and have, in fact, shown our people the way. I speak of workmanship. But, if our supposed traveller be interested in structural work, he will find the same unfavourable comparisons between our substantial, and in some cases, artistic, bridges, and the flimsy-looking girders of unvarying pattern which span American rivers; or, between our glazed brick, clean and water-tight tunnels, such as at Blackwell, and the dirty, dingy, and leaky holes, such as those

found in Chicago. Again, it is said for America that there is equality in the workshop and in social relations. This is not true. There is, certainly, a sort of free-and-easy, familiar conversational style between bosses and workmen; but it is merely superficial, and denotes no real social equality. As a matter of fact, the general attitude of the American workman towards his employer is more embittered than is that of the workman of this country. To be convinced of this one has but to read the newspaper accounts of such disputes as the recent one in the Pennsylvania coal fields.

The American industrial upheavals are characterised by violent scenes and lawless acts, in striking contrast with the quiet orderliness and regard for law which mark the settlement of industrial disputes in this country. The fact is, that there is less fellow feeling in America than here, either as amongst the working people as a class or as between the American people as a whole.

Nor could it be otherwise. The Americans are not a homogenous people. They are recruited, year by year, from nearly every country in the world, and, as a result, there are large numbers of people in America stamped with the seal of racial, as well as economic, inferiority.

The only sentiment which I noted as pervading all with whom I came in contact was that the Americans are a chosen people; that they do better things and have bigger things than any other people. I was shown at least half a dozen buildings which were said to be the "biggest on earth."

These idiosyncracies of the American people are sometimes said to denote vitality; they are regarded by American apologists as evidence that the Americans are really "awake." To me they simply indicated a neurotic and unhealthy condition. There is such a thing as being too wideawake, and therein lies, to my mind, America's danger.

America is undoubtedly a great country,—in the making,—but I think that Americans would do well for themselves if they were to decide to live a little slower. Otherwise they may find, when perhaps too late, that in the effort to "lick creation" they may themselves get prematurely used up in the process.

ALTERNATING CURRENT FOR LIGHT AND POWER

By Charles F. Scott, President of the Am. Inst. E. E.

THE above title immediately suggests the old-time controversy, alternating *versus* direct current. The present problem, however, may be more accurately stated,—alternating current only *versus* alternating current and direct current.

In discussing this before the American Institute of Electrical Engineers, the writer took occasion to say that the economical radius of direct current supply from a central station is so limited that even in a strictly direct-current system, if it covers considerable area, recent engineering prescribes a large alternating-current generating plant furnishing power to rotary converter sub-stations, and from these the direct current is distributed.

The problem, therefore, is this:—For general distribution for lighting and power service where the current is generated in alternators, is it desirable to utilise the current as alternating current or to convert it into direct current?

Before taking up in detail the various elements involved, the following statements may, in general, be considered as axiomatic:—

1.—Simplicity demands a uniform

system with elements as few as possible and requiring a minimum of attention. Converting apparatus requires rotating machinery and the presence of attendants, and these involve first cost, operating expense, complication and liability to interruption of service.

2.—In classes of service for which direct current possesses no advantage over alternating current, conversion is undesirable. For example, the simplest case is incandescent lighting. It is doubtful whether anyone would propose converting to direct current if incandescent lighting alone were to be supplied.

3.—In outlying districts or other territory where the output from a sub-station would be quite small, it would obviously not be economical to convert into direct current, as many of the expenses of such a sub-station would be relatively large, so that the cost per kilowatt for converting into direct current would be excessive.

These conditions limit the general problem, and the question may now be stated thus:—In those cases in which the conversion from alternating into direct current is commercially practicable is it necessary or desirable?

It will be readily granted that usually a large part of the service would be as satisfactory if operated by alternating as by direct current. With regard, then, to those elements in which there is a difference of opinion, are the reasons for the use of direct current sufficient to justify the increased complications and expense of the converting apparatus? To answer this intelligently we will consider it in two divisions:—

1.—In the utilisation of electric energy what advantages has direct current over alternating current?

2.—When energy is generated as alternating current, what disadvantages are involved in utilising it as direct current?

Taking up the first of these, let us consider the ordinary classes of service and the means of providing for them. Incandescent lighting may be considered as indifferent to the character of the current whether it is alternating or direct, provided the frequency be sufficiently high to prevent flickering. Arc lighting is most extensively carried on by the enclosed arc lamp, which is satisfactorily operated from direct current circuits, and also from sixty-cycle alternating circuits, so that there is no compelling reason for choosing either one current or the other as far as arc lamps are concerned.

In discussing motor service it is not the intention here to enter into a controversy as to the relative merits of alternating and direct-current motors. Both are in extensive use for nearly every kind of service. The induction motor is notable in having no commutator, and on account of its ability to stand various kinds of abuse. It is especially fitted for general distribution of power in all sorts of places, as such motors receive little or no attention.

For constant-speed work probably no one will question the superiority of the alternating-current motor from the standpoint of the man who uses the motor and pays for repairs. Any objections which may be brought forward will probably be urged on account of reasons applying to the supply system, such as power factor, starting current and voltage regulation. These items may be provided for by properly designing the system, and they cannot be regarded as legitimate objections to the use of the alternating current motor.

For variable-speed work the conditions are different. The fundamental difference is due to the fact that although there is a close correspondence between the performance of the induction motor and the direct-current shunt motor with constant field excitation, the alternating-current motor does not have an exact analogue to the direct-current series motor. It follows that induction motors cannot exactly duplicate all direct-current motors. Therefore, the results which may be desired must often be obtained in a way different from the methods employed with direct-current motors.

From the above summary it appears that all of the important classes of service for which current from a central station is used may be successfully under-

taken either by the direct current or by the alternating current, sometimes equally well, sometimes with the advantage on one side and sometimes with the advantage on the other side. The most important difference is probably in the case of variable-speed motors, and the importance of this will depend quite largely on the proportion of this kind of service. Although the alternating-current motor cannot exactly replace the direct-current motor, so that there may be some inconvenience in changing from one system to the other, yet when a new plant is being laid out it is probable that the cases are very rare in which it would not, on the whole, be practicable to utilise either alternating-current motors or direct-current motors.

To consider next the apparatus employed for producing and distributing current, the elements in the two systems may be set forth as follows:—

ALTERNATING CURRENT ONLY	ALTERNATING AND DIRECT CURRENT
Alternators	Alternators
Switchboards	Switchboards
Primary Mains	Primary Mains
Transformers	Sub-stations with
Distributing Circuits	Switchboards
	Transformers
	Switchboards
	Rotary Converters
	Switchboards
	Distributing Circuits

Comparing these in detail, the generating station in general will be substantially the same for the two systems, although a higher frequency will usually be employed if there is little or no conversion to direct current. The primary feeding system will also be substantially the same in the two cases, differing, however, in the number of points at which the transformation is made to the low voltage, and the distributing system is supplied with current.

The sub-stations for conversion into direct current constitute the great difference between the two systems. Sub-stations with converting apparatus are expensive to install and to operate. The cost of the sub-stations naturally makes it desirable to have as few as possible; hence, they are located at as great a distance apart as the distributing circuits will permit.

The cost of distributing circuits for direct current is, therefore, very much greater than for the low-tension, alternating-current circuits to which current is supplied from a large number of transforming points, since the alternating-current circuits are comparatively short, and the cost of copper is hence greatly reduced. This effects a saving not only in the cost of the conductors themselves, but also in subways and ducts, which are often limited in capacity and high in cost.

The liability to accident and interruption to service is inevitably greater in the system which converts to direct current than in that which merely transforms to a lower voltage, since the sub-station, with its switchboards and rotating machinery, intervenes between the generator and the consumer.

The storage battery is an element which is sometimes presented as a reason for adopting direct current, as it may be readily added to the system. It may, however, be used in connection with alternating-current distribution. A rotary converter may be employed for charging the storage battery, and, in turn, the battery can supply current through the converter to the alternating circuits. In this manner the battery may be related to the alternating system in substantially the same way that it is usually related to the direct-current system, except that the converter is between the battery and the service.

The foregoing general comparison between the two generating and distributing systems evidently favours the one which employs alternating current only. The introduction of converting apparatus, therefore, must be justified by advantages accruing in connection with the utilisation of the current which are sufficiently great to overbalance the extra cost and complication.

To change an existing direct-current system into an alternating-current system is in many cases a difficult matter. The circuits which are suitable for direct current may not be suitable for alternating current. The motors used for the direct current would, of course, be useless on the alternating circuits. These and other similar points complicate the general problem, and when an existing

direct-current plant is to form part of a large system such considerations often determine the plan to be followed.

The foregoing discussion applies particularly to large city plants for supplying lights and stationary motors for general work, and it has been assumed that the entire service is supplied either by direct current or by alternating current. There are, however, some cases where a combined service is advantageous, alternating current being supplied for certain districts, and direct current for others.

In cities, a combined service for general distribution is sometimes applicable for furnishing direct current from substations to districts which have previously been supplied by direct-current generating plants, while alternating current is furnished to the outlying parts. The same generators may be used for both classes of service, and may supply them simultaneously. Quite similar results may be attained from a direct-current generating plant, the alternating current being obtained from inverted rotary converters.

In smaller towns a combined service from an alternating-current plant is often used for supplying railways by sixty-cycle rotary converters in connection with general lighting and power, the latter service being entirely by alternating current. In many cases the lighting and railway work can be operated from the same bus-bars, as the automatic compounding of the rotary converters is such as to make the voltage upon the general system sufficiently constant for lighting service.

Probably the most pertinent conclusion to be drawn from a discussion of this kind is that there is no ideal system, and no panacean plan which can be universally applied. Existing and local conditions, special requirements and the relative importance of the various classes of service to be rendered must all be taken into account in determining what will be adequate in an individual case.

The systems here discussed have an important and far-reaching influence upon industrial life and social activity aside from their engineering aspects. It would be difficult to find an agent more instrumental in bringing about the unification and concentration of diversified industries and interests than electric energy in the form of alternating current.

A generation ago it would have defied the imagination to discover any natural connection between such widely different agents as horses pulling street cars, locomotives drawing railway trains, gas for lighting houses and streets, water operating elevators, stoves for heating and cooking, and engines of every sort and class doing a hundred kinds of work. But all of these and many others are in common being superseded by the electric current, which does not merely replace, but develops, expands, and transforms. It is notable that all of this varied service is to be supplied from alternating-current generators; also that the outcome of the evolution of plans for general distribution and for railway work is identical in that alternators of the same frequency are being installed for both, so all could supply current to a common universal system.

THE MODERN POWER PROBLEM

II. —HYDRAULIC POWER, GAS PRODUCERS, AND INTERNAL COMBUSTION ENGINES

By Professor John Joseph Flather

The first part of Professor Flather's article, dealing with electric and compressed air power, appeared in the March number. In the concluding portion, here given, reference to electric power transmission from cheap fuel centers and to oil fuel is made briefly incidental to the discussion of remaining principal division of the subject.—THE EDITOR

HYDRAULIC POWER

MENTION has been made of the use of the hydraulic motor as a factor in the sub-division of power, but this motor is being used to such a limited extent for this purpose that it need not be considered here.

There is, however, a growing field of usefulness for hydraulic power in manufacturing operations which is peculiar to this agent alone, namely, in forging and similar work. Where hydraulic power exists for this service it is also generally used for a variety of purposes which could be accomplished just as well, and often more economically, by steam or compressed air; but in forging operations where heavy pressures are required, hydraulic power is infinitely better than either.

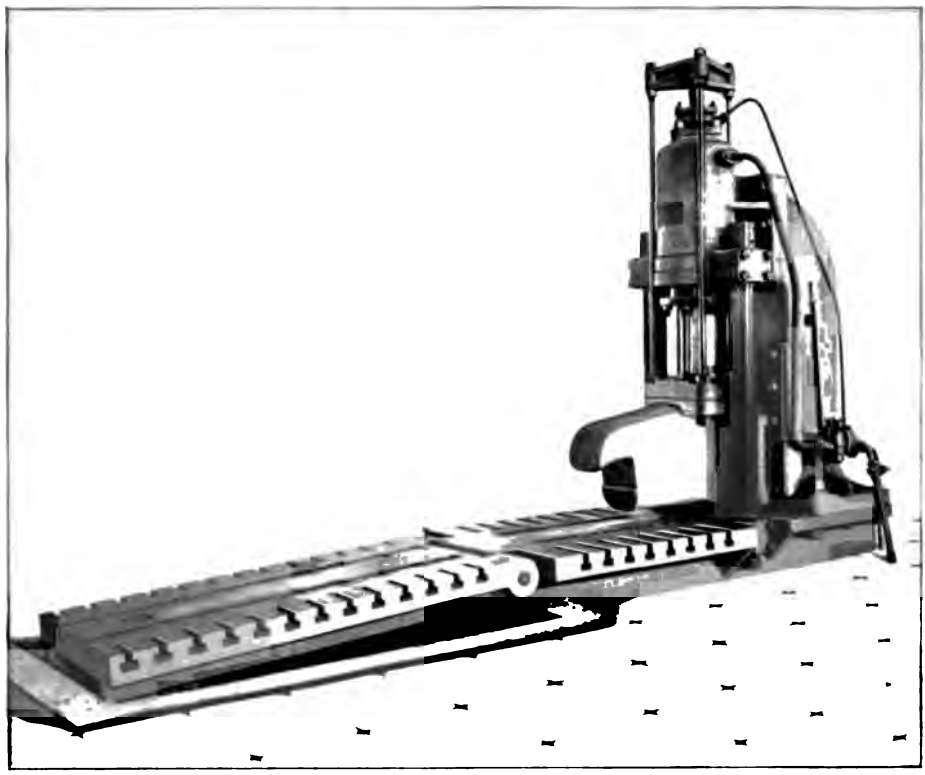
The compressibility of air is an objection in many lines of work, and it is now well recognised that the effect of a hammer blow is oftentimes merely local. The pressure applied in forging a body of iron or steel should be sufficient in amount and of such a character as to penetrate to the centre and cause flowing throughout the mass; as this flowing of the metal requires a certain amount of time, the pressures should be maintained for a corresponding period.

Hydraulic pressure instead of a hammer blow should, therefore, be used to work it into shape. Under its action the forging is slowly acted upon and the pressure is distributed evenly throughout the mass, whereas under the high velocity of impact of the hammer the metal does not have time to flow, and thus internal strains are set up in the mass which may cause serious results, especially with certain steels which have not the property of welding.

Besides the fundamental defects incident to the method, it is very troublesome to use a hammer in certain lines of work on account of mechanical difficulties of manipulation. The quality of the steel is very much improved by the processes of hydraulic forging, and we find a marked tendency to substitute this method in a wide variety of work in which presses are employed varying in capacity from 20 tons to 14,000 tons.

The success which has attended the use of hydraulic power in forging is causing it to be applied to other and similar work to an increasing extent. In boiler works, railway and locomotive shops, bridge works, and shipyards it is used along with compressed air, but where heavy pressures are desired hydraulic power is greatly to be preferred; hence we find it operating machines for punching and shearing heavy plates and beams, riveting machines,—stationary and portable,—flanging and bending machines, tube upsetting machines, wheel and crank-pin presses, lifting jacks and hoists of all kinds. For heavy boiler work hydraulic riveting seems especially well adapted, as an intensity of pressure can be brought to bear upon the plates which is obtained by no other method.

It has already been stated that com-



HYDRAULIC BOILER FLUE FLANGING MACHINE, MADE BY THE LEEDS ENGINEERING AND HYDRAULIC COMPANY, LTD., LEEDS, ENGLAND

pressed air, as now used without reheating, is not at all efficient as a source of motive power, since the combined efficiency of compressor and motor, even under favourable conditions, is not more than 50 per cent. of the available energy put into the compressor. In other cases the efficiency is as low as 20 per cent. In the transmission of air, within reasonable limits, the loss in transmission if the pipes be tight need not be considered; for although there is a slight loss in pressure due to the frictional resistances of the pipes, yet there is a corresponding increase in volume due to drop in pressure, so that the loss is practically inappreciable.

There should be no comparison between the cost of power by compressed air and its brilliant rival, electricity, since each has its own field of usefulness; yet it may be interesting to note for our present purposes the efficiency of electric power. A modern shop generator belted from an engine will have an efficiency of about 90 per cent. when working under favourable conditions; but as the average load is ordinarily not more than two-thirds full load, and often much less, the efficiency will not usually be more than 85 per cent. Since the engine friction was added to the losses in compression, so also it should be considered here, in which case the efficiency of generation will lie between 75 and 80 per cent. With a three-wire, 220 volt system, which is very suitable for ordinary shop transmission when both light and power are to be taken off the same dynamo, the loss in transmission need not be more than 5 per cent., so that the efficiency at the motor terminals will not be far from 75 per cent. With motors running under a nearly constant

full load, the efficiency of motor may be 90 per cent., but with fluctuating loads this may fall to 60 per cent. at quarter load.

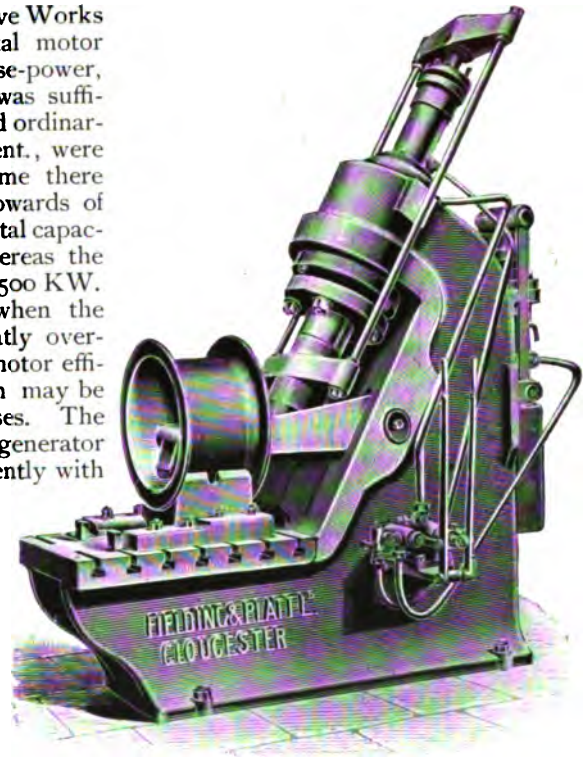
In numerous tests made by the writer the average load on several motors in machine shops has been only about one-third of the rated capacity of the motor. It is interesting to note that in tests made at the Baldwin Locomotive Works it was found that, with a total motor capacity aggregating 200 horse-power, a generator of only 75 KW was sufficient to furnish the current, and ordinarily only 60 KW, or 40 per cent., were required. At the present time there are in use at these works upwards of 300 motors, with a combined total capacity of 2200 or 2300 H. P., whereas the generator output is only about 500 KW.

Under these conditions, when the driven machines are not greatly overmotored, we may assume a motor efficiency of 80 per cent., which may be less or greater in individual cases. The combined efficiency, then, of generator and motor working intermittently with fluctuating loads, will be about 60 per cent. of the power delivered by the engine.

For greater distances than those which occur in plants of this character, the loss in transmission will be greater, and higher voltage must be employed in order to keep down the line loss. While it is possible to put in conductors sufficiently large to carry the current with any assumed loss, yet the cost of the line becomes prohibitive with low voltage.

Where cheap fuel is available it is found in most cases that electric power can be generated at the works more cheaply than it can be purchased from a central station; especially is this the case if the exhaust steam be used for heating purposes. In isolated plants the cost of transmission is very small, as compared with the total cost of generation; whereas in the average central station the cost of transmission, which includes interest and depreciation on pole line, usually constitutes a large percentage of the operating cost. Where the cost of fuel is high, electric power can often be purchased more cheaply from a central station.

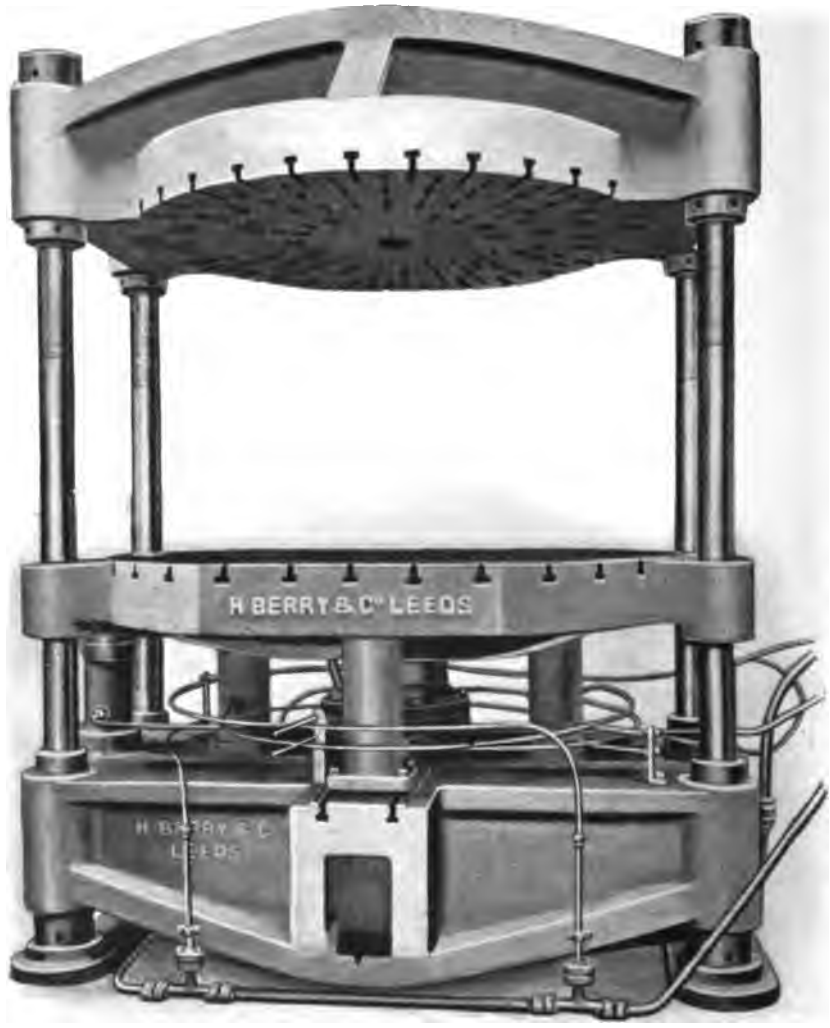
Recent developments in electrical transmission have been very marked. Distances have been gradually increased until it is now possible to carry electrical



HYDRAULIC MACHINE FOR FLANGING ADAMSON BOILER FLUE RINGS. MADE BY MESSRS. FIELDING & PLATT, LTD., GLOUCESTER, ENGLAND

energy economically and in commercial quantities over distances as great as 150 and even 200 miles. There has been a steadily increasing tendency to raise the line voltage in such transmissions, and to-day we find in successful operation voltages as high as 40,000 and even 60,000, as compared with the 4000 and 6000 volts of a few years ago.

So far as present practice is concerned, the limit of use of high voltages must be sought beyond the transformers and outside of generating and receiving stations. As now constructed, the line is that part



HYDRAULIC FLANGING PRESS, MADE BY MESSRS. HENRY BERRY & CO., LEEDS, ENGLAND

of the system where a limit to the use of higher voltages will first be reached. In order to avoid the temporary arcing and leakage between the several wires, these must be placed a considerable distance apart, and this, with higher voltages, may lead to a modification in construction of pole line. The plan of substituting a series of steel towers, about 90 feet in height and 1000 feet apart, is being seriously contemplated.

In this case it is proposed to suspend the wires from tower to tower and have them about 9 feet apart. While expensive in first cost, it is thought that the satisfactory working of such an arrangement and freedom from breakdown with the low maintenance and depreciation charges involved would warrant the investment.

A more serious difficulty is found in the insulator, which is generally looked upon with distrust for the higher voltages in use to-day. With a more perfect in-

sulator there would appear to be no good reason why the present maximum voltages should not be exceeded.

The possibility of electrical transmission thus permits of the utilisation of available sources of power at great distances from the centre of distribution; but while it is interesting to know that a certain amount of power may be transmitted a given distance with a high degree of efficiency, it is more important to know whether the same amount of power could be obtained at the objective point more economically by other means.

It has been suggested that the future of long-distance transmission depends largely upon the development of oil as a fuel; but at the present time the outlook for oil fuel in general competition with coal or long-distance electric transmission is not encouraging. While the development of new American oil fields has increased the visible supply and brought about increased activity in the use of liquid fuel, yet it is doubtful whether the advantages would be sufficient to cause the oil to come into general use as a fuel, since, with a limited production and an increased demand for this and other purposes, the cost would be correspondingly increased.

A number of railroads near the oil producing centres have equipped their locomotives to burn this fuel, and it is used to some extent to fire marine boilers, and with great satisfaction, since its displacement for a given heating value is only about one-half that of coal, and the labour cost is materially reduced.

Oil fuel is also used quite extensively in some places as a steam producer in power plants, but it is hardly probable that liquid fuel will be a serious competitor of coal, notwithstanding its many advantages.

At the present time, as far as power for manufacturing plants is concerned, it is largely a question of transportation, whether oil can be laid down and handled at a given point more cheaply than coal. It is probable, however, that oil fuel will supply a local demand in certain sections where transportation charges will permit its use at a low cost, and it is there that it may become a competitor of electrical transmission.

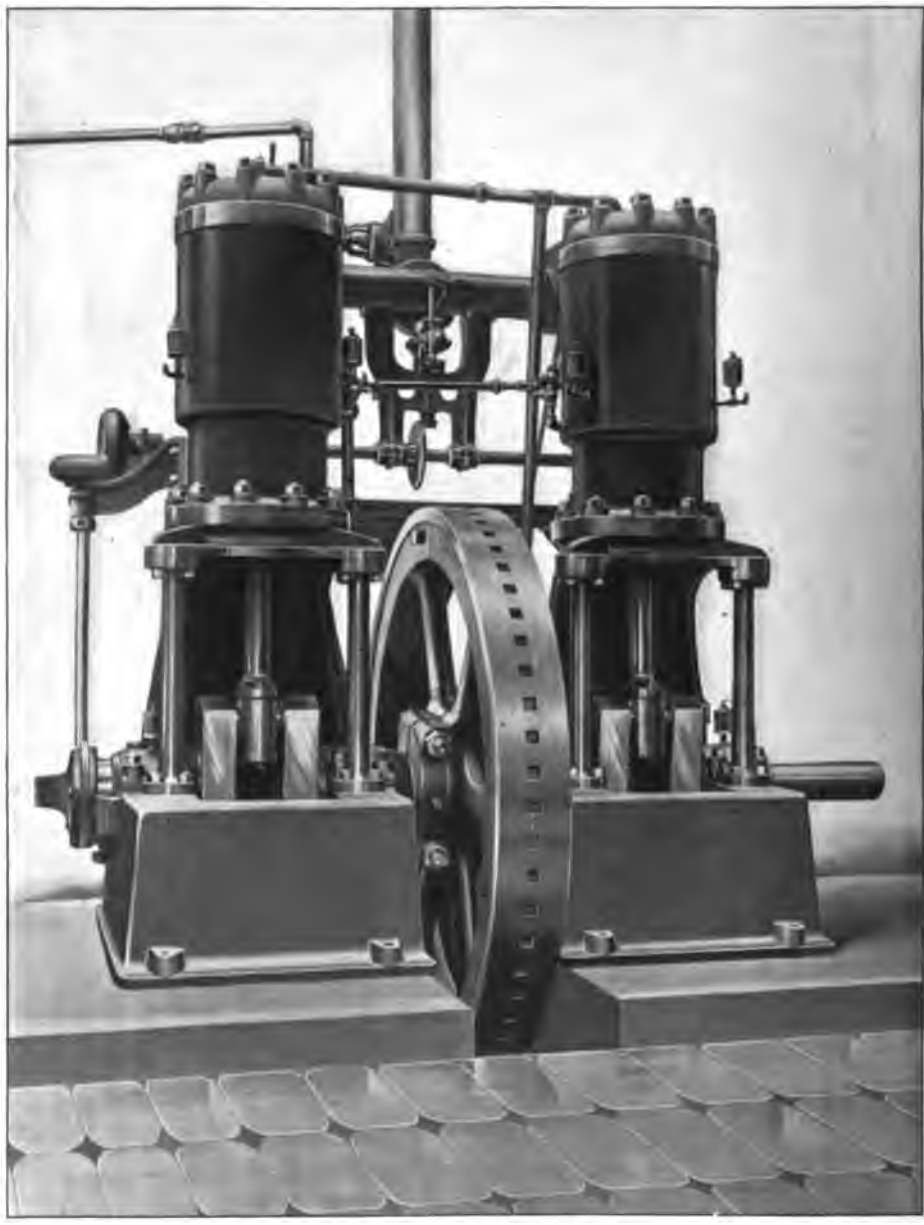
GAS PRODUCERS AND INTERNAL COMBUSTION ENGINES

One interesting phase of the power problem which forcibly presents itself to the engineer at the present time is the vast possibilities possessed by the modern internal combustion engine, which includes the various types of gas and oil engines. While its use as a motor in industrial establishments has been somewhat limited, there is a marked tendency to employ the gas engine in manufacturing works, and a consideration of its advantages and cost of operation, together with its high thermal efficiency and possibility of still further improvement, indicates that for many purposes both steam engines and electric motors may be ultimately replaced by gas engines.

While the first cost of electric motors in the smaller sizes is considerably less than the cost of well-made gas engines of similar capacities, the saving during the first six months of service, due to the more economical operation of the gas engine, will often more than compensate for the difference in first cost. That the gas engine, in both large and small sizes, has reached a point in its development where it can fairly rival the steam engine in reliability and satisfactory running qualities there can be no question. In point of fuel economy a gas engine of moderate size is on a parity with the largest triple-expansion steam engines, and will give a horse-power on less than one pound of fuel.

The high price of gas in many places has contributed largely to those causes which have prevented a more common use of the gas engine as a motor. For this reason the gas engine has generally been used, not so much because of its high efficiency as a thermodynamic machine, but rather on account of its convenience and saving in labour.

It is to producer gas that we must look for any marked increase in the use of the gas engine. Fortunately the manufacture of this gas has reached a



A 275 H-P. DOUBLE-CYLINDER VERTICAL GAS ENGINE, BUILT BY THE STRUTHERS-WELLS CO., WARREN, PA., U. S. A.

high state of development, and there are now in successful use several processes by which power gas can be made from cheap bituminous coals, as well as anthracite and coke. The leanness of such gases renders them less effective per cubic foot, as compared with the richer coal gas or even water gas; but this difference is more than compensated for by the low cost of production. It nites, or wood. With bituminous coal means must be provided for removing the tar and ammonia and other products of distillation.

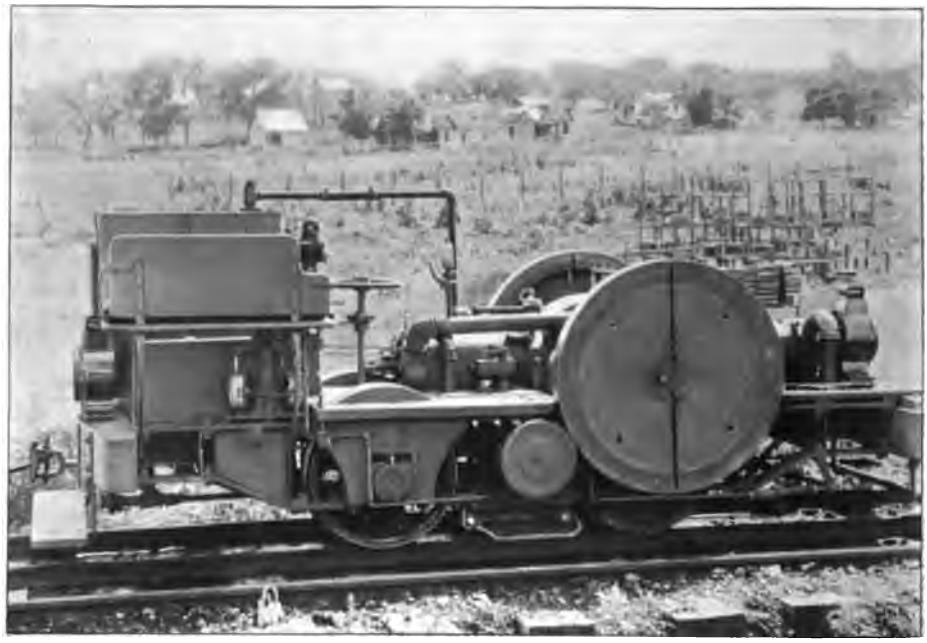
The process of generation in some of the more recent producers is entirely automatic and depends upon the demand of the engine, so that no storage capacity is required. The economy of these small producers is shown by tests which

GAS ENGINES AT DIFFERDINGEN, LUXEMBURG, USING GAS FROM BLAST FURNACES, INSTALLED BY THE JOHN COCKERILL COMPANY, SERAING, BELGIUM

is upon such power gas that the commercial future of the gas engine as a general motor depends.

A growing factor in gas engine practice is the small gas producer. These generators are very simple in operation, and furnish a convenient and economical means of obtaining power at a much lower rate than with the ordinary city lighting gas. Generally small anthracite coal or coke is used; but several methods employ bituminous coal, lig- give 1 horse-power on a 16 horse-power engine with a consumption of only 1.1 pounds of fuel. For engines above 40 horse-power 1 horse-power can be obtained on ⅞ pound of fuel.

The gas engine industry received a signal impetus when it was discovered that blast furnace gases could be readily utilised direct in combustion engines without the intervention of boilers and without any special purifying processes. A still more important circumstance,



A GASOLINE LOCOMOTIVE FOR USE IN CONNECTION WITH INDUSTRIAL RAILWAYS IN LARGE WORKSHOPS AND ALSO IN MINES MADE BY THE WEBER GAS AND GASOLINE ENGINE CO., KANSAS CITY, MO., U. S. A.

which is far-reaching in its results, is the fact shown by Professor Hubert, of the Liége School of Mines, that the superior economy of the gas engine enables equal power to be obtained with 20 per cent. less consumption of furnace gas than was formerly used in the generation of steam. The successful employment of large combustion engines in this way utilises vast sources of power which a few years ago were allowed to go to waste, or, at most, were used very inefficiently.

The high thermal efficiency of the gas engine has long been recognised, and the possibility of further development is a promising factor in this field. The already accomplished efficiency of 38 per cent. reported by Professor Meyer, of Goettingen, greatly exceeds the maximum theoretical efficiency of the steam engine and more than doubles its actual best obtainable working efficiency; but the end is not yet.

With higher compression even greater efficiencies may be expected. But with high compression there is danger of premature explosion, due to the generation of heat in compressing the gas in the presence of oxygen. For this reason Herr Diesel compresses the air separately. Under a pressure of 500 pounds, or more, which is used in the Diesel motors, the air becomes very hot and readily ignites a charge of liquid fuel which is injected into the compression chamber. There is no explosion; combustion occurs while expansion goes on, and the heat generated disappears in the form of work.

Efficiencies of 30 per cent. or more have been obtained with blast furnace gases, which contain a very small percentage of hydrogen, and this, with the high rates of compression which can be carried, has led to the advocacy of non-hydrogenous mixtures in large engines. Certainly very high rates of compression may be had with a non-hydrogenous producer gas without fear of premature ignition, and it has the additional advantage of economical production.

The practice of making the cylinder in combustion engines act alternately,

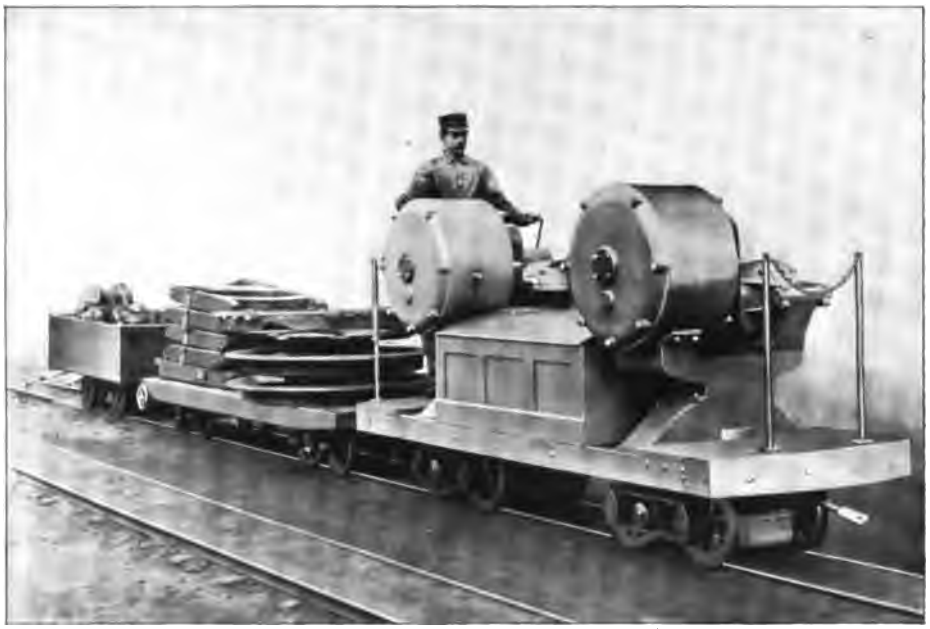
first as air compressor, then as motor, has the advantage of greater simplicity; but it means immensely larger engines for the same power, since the number of effective impulses is thus cut in two.

The danger of pre-ignition and consequent severe shock on the engine also necessitates very heavy construction in the smaller engines in order to obtain a reasonable degree of safety in operation. Moreover, the smoothness of action is greatly retarded with this form of engine, especially if the governing is controlled by the "hit and miss" method, in which the regulation is effected by varying the frequency of the explosions, thus causing great variations in the driving torque.

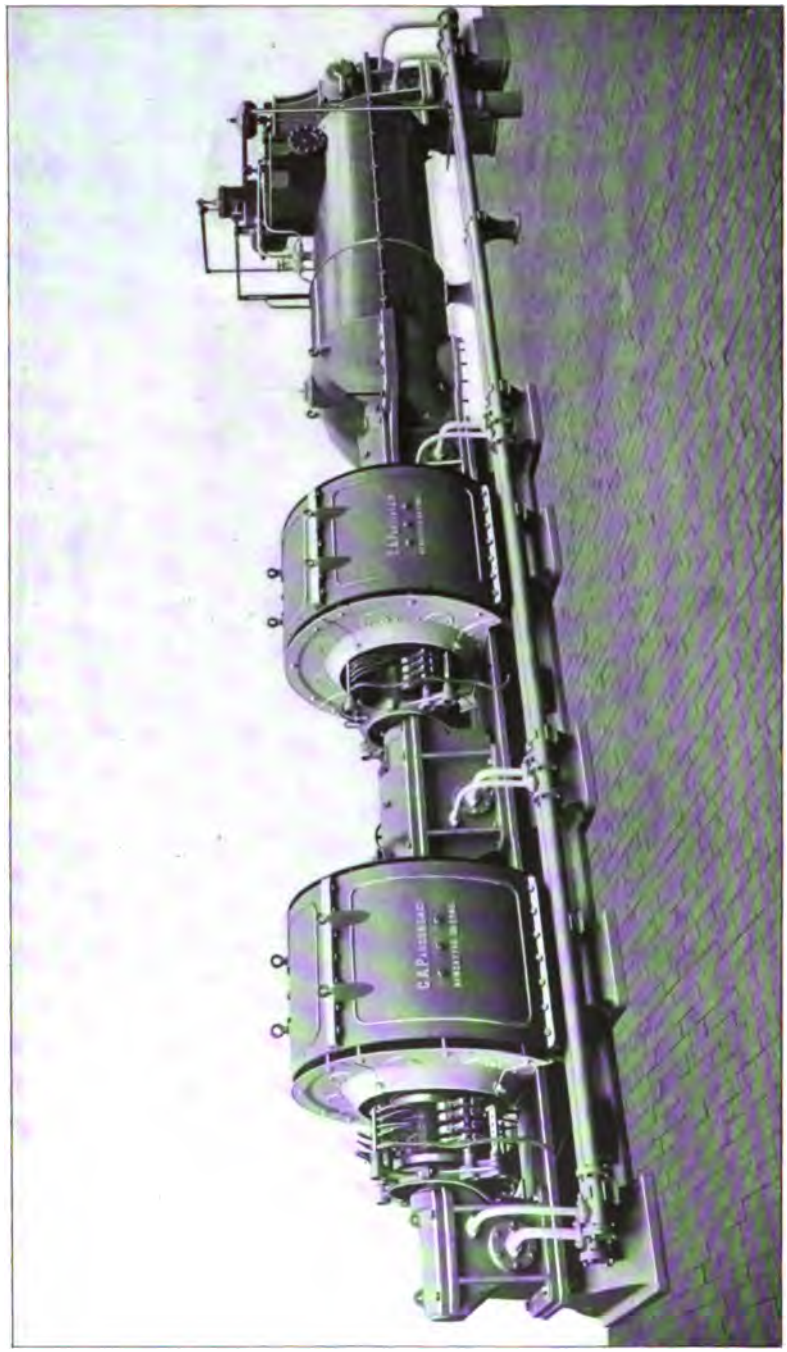
Various expedients have been employed to overcome these defects, such as the use of multi-cylinders and different methods of control; but the size and cost of engine has been increased, rather than decreased. Notwithstanding these well-recognised defects in the four-cycle type of engine, it constitutes by far the largest class in use to-day of what may be called successful gas engines.

More recently very satisfactory results have been obtained in the construction of two-cycle engines. In some of these separate pumps are employed to compress the charge of gas and air, which ignites and burns as it enters the cylinder. Higher compression is thus obtained without fear of pre-ignition, and this permits smaller clearance spaces, with attendant advantages. If the engine is single-acting, an impulse is obtained every revolution, which thus insures better speed regulation, as well as doubles the power for a given size of cylinder.

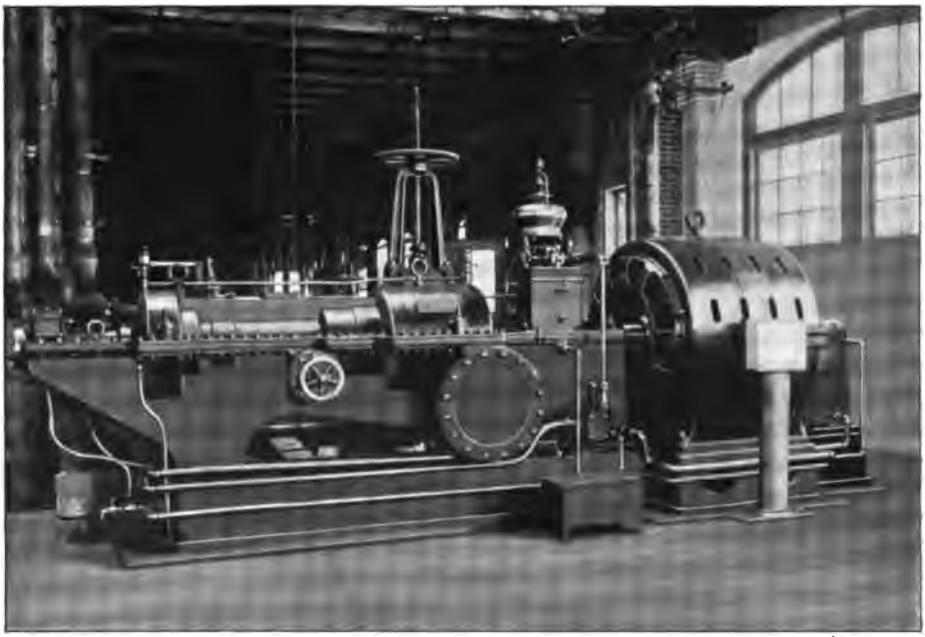
The highest thermal efficiency yet attained, namely, 38 per cent., has been secured with a two-cycle type of engine, which compresses the air and gas in separate pumps to a nominal pressure of eight or ten pounds, the air under this pressure being used to scavenge the cylinder toward the end of expansion. After the unconsumed products of com-



AN ELECTRIC STORAGE BATTERY LOCOMOTIVE FOR SIMILAR SERVICE, MADE BY THE C. W. HUNT COMPANY, NEW YORK



A 1000-K.W. STEAM TURBINE COUPLED TO TWO 500-K.W. DYNAMOS. SUPPLIED TO THE NEWCASTLE AND DISTRICT ELECTRIC LIGHTING COMPANY, BY MESSRS. C. A. PARSONS & CO., NEWCASTLE-ON-TYNE, ENGLAND



A 400 K.W. STEAM TURBINE ALTERNATOR, BUILT BY THE WESTINGHOUSE MACHINE CO., PITTSBURGH. THIS OUTFIT FURNISHES CURRENT FOR ELECTRIC MOTORS AND LIGHTING AT THE WORKS OF THE YALE & TOWNE MFG. CO., AT STAMFORD, CONNECTICUT, U. S. A.

bustion have been forced out by the fresh air, the cylinder walls having been cooled thereby, a charge of gas is admitted and compressed to a pressure of 150 to 175 pounds, and is then exploded, as in the usual method. This engine is double-acting and receives a charge each side of the piston; thus two impulses are received during each revolution, in a manner precisely similar to that of a steam engine.

Whether these engines will be as satisfactory for small motors remains to be seen. It is possible that the greater complication of details in the two-cycle types, as compared with the simpler four-cycle engine, will cause the latter to continue to give the greater satisfaction, at least for the smaller sizes.

The size of gas engines has rapidly grown during the past two years, as shown by the fact that one manufacturer is now constructing a gas engine of 2500 H. P., and is prepared to build up to 5000 H. P. The development of the large gas engine is closely connected with the evolution of the fuel gas processes, and it is noteworthy that the first gas engines in Great Britain above 400 H. P. were operated with producer gas, while many of the large gas engines in Continental Europe have been built for use with blast furnace gas. The use to which large gas engines are put is about equally divided between the operation of blowing engines for blast furnaces and the driving of dynamos for general power distribution.

While the gas engine in the larger sizes is thus used extensively for the generation of electric light and power, a growing tendency is observed to use gas engines direct as motors. A number of railway and other machine shops have been equipped with moderate-sized gas engines suitably located about the works, and, in addition, thousands of horse-power are used in the smaller sizes for a wide variety of purposes, including village water-works, isolated lighting stations, and manufacturing plants of all kinds.

With the possibilities of high thermal efficiencies we may look with much hope

upon the still higher development of cheap fuel gas processes that will bring the gas engine into very general succession to the electric motor for many purposes, for it will doubtless be found that gas transmitted from a central gas-making plant at a manufacturing works into engines located at points of use will effect a material saving in the utilisation of power over any existing methods.

It is not to be presumed that the gas engine will displace either the electric motor or the steam engine. Each has its legitimate sphere of usefulness, and each will be more highly developed as the result of direct competition. Yet the economies already obtained indicate that the field of the gas engine will be extended more and more into that of the steam engine and the electric motor.

Many of the questions involved in this consideration are at the present time in a transitional stage. The reciprocating steam engine has reached a high state of development, but it is not probable that it has attained its highest degree of perfection. While a performance of less than nine and one-half pounds of steam per horse-power-hour has been obtained, even better results may be anticipated. The use of high-pressure, superheated steam in compound, jacketed engines involves more perfect lubrication, and this may demand modification in existing valve types. However this may be, the outlook is promising for still higher efficiencies. Whether this will mean cheaper power than can be obtained in other ways will depend upon many conditions. From this point of view the present activity in the construction and development of the steam turbine is of interest to engineers and power users. The steam consumption of a modern steam turbine of moderate size compares very favourably with that of the better class of large reciprocating engines, but what is of greater importance is the evident superior steam economy under variable loads. The steam consumption per horse-power-hour varies little from one-third to full load; at overloads the economy, as shown by numerous tests, may be even better. This feature predestines the steam turbine to the special field of electric lighting and power generation, where it must inevitably become a formidable rival of the larger-sized, slow-speed, reciprocating steam engine.

The high rotative speed of the steam turbine is a prominent factor in favour of its adoption in connection with electrical generators, since the cost of the generator and of the equipment ought eventually to be very materially reduced; but for many lines of work the high rotative speed of the present types of steam turbine is prohibitive, nor can it be adapted successfully to belt driving. However, it is fair to presume that the present limitations of the steam turbine are not insuperable, and that the attention which is now being given to its development will evolve a more universal type of motor adapted to general power purposes with large and small units alike.

ECHOES FROM THE RECENT PENNSYLVANIA COAL STRIKE

ON BEHALF OF THE MINE OWNERS AND OPERATORS

By George F. Baer, President of the Philadelphia & Reading Coal and Iron Company

EVEN with the famous strike fresh in memory which occurred in the engineering trades of Great Britain in 1897 and extended over a period of about seven months, with immense losses for bothemployers and employees, it can safely be said that there has never been a more important labour disturbance anywhere than the Pennsylvania coal strike of last year, which covered about the same length of time. There was not only cessation of work, but violence in aggravated form, destruction of property, and bloodshed.

Coal is something upon which everybody is more or less dependent for comfort, indeed existence, and the coal famine which began to make itself seriously felt as a result of that strike with the setting-in of the winter of 1902, promised to be disastrous in many ways. The return to work of the miners, pending an investigation of their alleged grievances, and the appointment of a strike commission to conduct that investigation, brought about through the unofficial intervention of the President of the United States, are matters of general public knowledge.

The public hearings of that commission were closed a few weeks ago, the final session being devoted principally to the presentation of arguments on behalf of the mine owners and operators by Mr. George F. Baer, president of the Philadelphia & Reading Coal and Iron Company. Mr. Baer's address was a carefully prepared review of the leading features of the strike, with a request simply for justice for the coal-producing companies, and while his remarks cannot well be reproduced here in full, extracts from them are given

Geo. F. Baer

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which undoubtedly will be read with interest.—THE EDITOR.

In the development of the natural resources of the earth it is necessary for men to combine both their capital

and their energy. Railroad and steamship lines, great steel plants and workshops of every kind can be created only by a combination of capital and energy. Through an adaptation and enlargement of Roman laws we have developed the modern business corporation, but are apt to overlook the part these business corporations play in the distribution of wealth. Their stockholders are many, scattered far and wide, and the business is not owned, as many people suppose, by a few very rich men. The profits made in any large business, carried on by a firm consisting of one family, or a very few persons, are distributed among these few; but a successful business carried on in corporate form distributes its profits among the many, and, therefore, necessarily tends to a greater distribution of wealth.

I think there is, from lack of thought, much confusion in the minds of many people as to the rights, powers and duties which properly belong to industrial organisations, including both capital and labour organisations. In general, no one denies the right of men to organise for any lawful purpose; but the right to organise, and the power of the organisation when organised, must still be governed and controlled by the general law of the land under which individual and property rights are protected.

We constantly hear the phrase:—"Capital organises. Why may not labour organise?" As if this settled the problem. But capital cannot organise for an illegal purpose. Organised capital is subjected to sharper scrutiny than any other kind of organisation. A possible violation of individual rights is at once seized upon by the public as requiring some new and drastic law, if existing laws are not sufficient to meet public expectations. For example, may capital organise in such a way that one manufacturer may employ pickets to surround the establishment of another competing manufacturer to prevent ingress or egress to the works, or interfere with the sale of its commodities by intercepting its customers, or interfere with the transportation of its products and the orderly conduct of the rival business? We concede to organised labour the same rights that we claim for organised capital. Each must keep within the law. There cannot be one law for citizens and corporations and another law for labour organisations.

The lawlessness in the coal regions was the direct result of mistaken theories of the rights of the Mine Workers. It will not do to say that the leaders have not encouraged violence and crime. It is true, no doubt, that they did not directly advise it. They at times counselled against it and issued paper proclamations calling for peace, and at other times they have expressed regrets for it. Nevertheless, they are legally and morally responsible for the situation they created, and from which this violence and crime resulted.

They complain bitterly of the decisions of the legally constituted courts whereby riotous conduct, unlawful destruction of property and interference with legal rights of citizens are simply restrained. They even demand of their political supporters the passage of laws which will place trades unions above and beyond the customary and the ordinary jurisdiction of the courts. They blindly refuse to see that the peace and prosperity of the community and the rights of the citizen can be maintained only through the supremacy of the law and its just and equal administration. The overthrow of the civil power, whereby whole communities are at the mercy of the mob, so delights them that they cry out lustily against the soldiers who are sent to protect life and property. Why this denunciation of courts, of police, and of soldiers, if the measures to support a strike are to be only peaceful and persuasive? The law is a terror only to evil-doers. In the exercise of lawful acts we need fear neither courts, police, nor soldiers.

We have been told time and again how boys to the number of over twenty or thirty thousand in the coal regions have been admitted to membership in the Mine Workers' organisation; how foreigners, without reference to the fact as to whether they are or are not American citi-

zens,—foreigners of many nationalities and speaking diverse tongues,—with the boys, compose a majority of this organisation. These boys, like most boys, have not been disciplined to reverence law and order, and we do not expect boys to behave very well unless they are under strong restraint. The foreigners, many of them, have been governed in their old homes by stringent police regulations. The law, in the person of a policeman or a gendarme, confronted them everywhere. They have come to this country with confused ideas of what free government means. The distinction between liberty regulated by law, and license, is practically unknown to them. Therefore, when a powerful organisation of which they are members, led by men who are upheld and encouraged in a respectable community, tells them that force may be used to compel men to join their union, that scabs should be ostracised, that they are given power to suspend operations at a colliery where the employees do not join the union, is it not a direct invitation,—nay, more,—a command to commit the violence and crime that characterised the reign of terror in the mining regions?

Men who teach these false doctrines, pose as they may, are inciting to riot. Every day they saw the results of their work in outrages against persons and property. They made no reasonable effort to restrain the violence. They even ease their conscience with the fallacy that until a man is convicted in the courts he is guilty of no crime, and, therefore, they can shut their eyes to what is going on around them.

The legal responsibility they incur gives them little concern. They assume that juries selected from among their own members or sympathisers will not find them guilty. They will not become incorporated for fear of civil suits resulting in heavy damages. Still, the moral and legal responsibility exists, even though there is at times no adequate remedy for its enforcement.

We do not object to our employees joining labour organisations. This is their privilege. But we will not agree to turn over the management of our business to a labour organisation because some of our employees belong to it. Our employees, union and non-union, must respect our discipline. It is essential to the successful conduct of our business, and is peculiarly necessary in mining operations to prevent accidents. We must be left free to employ and discharge men as we please. If any of our officers abuse this privilege, then it is our duty to hear the case and review the action so that substantial justice may be reached. But we do not admit the right of an organisation, the moment we exercise the power of discipline, to coerce us, before inquiry, by strike, or interference with our management.

The employer ought, I think, to meet his employees personally or a representative of such employees, provided such representative acts only for the particular employees and does not act in the interests of persons who are not employees of the particular colliery. To illustrate,—in a controversy as to conditions existing at one colliery, the employees of that colliery must limit their demands to the particular conditions affecting that colliery, and if they see fit to be represented by some one acting as their attorney,—we do not care what name they give him, he may be president, or a vice president, or anything else,—he must be limited in the same way, he must not inject a theory as to what would be fair towards employees of another company a hundred or a thousand miles away.

It is on this account that we have objected to the interference of the president of the United Mine Workers in our business. If he simply represented our own employees and was acting exclusively for them, there could be no objection to dealing with him. But he represents an organisation having for its object some Utopian scheme of uniformity of wages and conditions in the mining of coal all over the United States. And instead, therefore, of considering only the questions at issue between our employees and ourselves, he is considering a general proposition which relates to all the coal miners dwelling under the

sun. The fact that the miners' organisation does restrict the quantity of coal a man may mine is clearly proven. It is not only proven, but it is defended as a right. Restriction on production, limiting the quantity a man may produce, seems to be based on the theory that this is essential to give employment to the many. The illustration given by one of the miners' attorneys was this, that if there is only a loaf to divide, you must divide it equally and give no one man more than his just proportion. The illustration is fallacious in this, that it is not germane to the subject. Labour is not a division of an existing thing. It is a power which produces things. Labour is not the loaf, but that by which in various forms the loaf is produced. Any restriction, therefore, on labour must necessarily reduce the number of loaves which are essential to feed the hungry.

To limit the right of exertion, of work, is to limit production. It is not only a wrong done to the individual, but it is a violation of sound economic principles, and, therefore, an injury to society. The ultimate effect of restricting production so as to divide employment and increase wages, must be to keep on dividing the wage fund as often as new men seek employment. There must be a limit to an increase of wages, but there can be no limit to the increase of workmen. The process must inevitably lead to the destruction of the industry or the reduction of the wages of every man to a sum barely sufficient to sustain life. Wages can increase only when each individual is left free to exert himself to his fullest capacity, thereby creating wealth, which, in turn, gives new employment,—creates demand for commodities and demand for workmen to produce them. Only in this way can the wage fund be increased.

The country is agitated over the possible dangers to the common welfare by combinations of capital. These combinations, or rather consolidations of many interests into one common company, are all based on the theory that they will result in greater economy, that the cost of production will be decreased, and that the public will be benefited in many ways, especially by regularity of production, stability of employment and reduction in cost to the consumer.

The criticisms as to over-valuation and capitalisation are financial questions, and only indirectly affect the public economic questions. If men see fit to invest their money in watered securities, that is their business, and the public is not responsible for ultimate losses. Economic laws will in the final windup work out the financial problem. But the public are rightly anxious as to the effect on the consumer.

All free men oppose monopoly. It is instinctive, and the possibilities of it alarm us. The mere fear of it suggests all manner of devices to prevent it. It is unquestionably true that if the recent combinations of capital, instead of proving a benefit to the public, as their organisers honestly believe, shall prove detrimental and result in creating monopolies guilty of extortion and oppression, legal and peaceful remedies will surely be found to curb their rapacity and oppression. But these large industrial combinations produce only things which are desirable, not absolutely necessary to sustain life. If the price of steel or any other like commodity is too high, or its production is stopped by striking workmen, for the time being, because of low wages, or by owners because of low profits, the public will be put to temporary inconvenience, but it can cause no general suffering.

But if we are over-anxious as to the probable effect of these mere possibilities of monopoly (I say possibilities, because it is not probable that in a rich, energetic country like ours any such industrial monopolies can be either created or maintained) what must be the measure of anxiety as to placing the control of the fuel of the country in one organisation, and that, too, an organisation without capital or responsibility?

Fuel is the life's blood of our age. It is as essential as food. Food production can never be monopolised. However low the wages and small the reward of the tillers of the soil, the labour reformer has not succeeded in controlling

farming. The farmers know no restriction in hours of labour.

But what of fuel? Without a dollar invested in property, the fuel of the country has been absolutely monopolised. Not a ton of coal could be mined in the United States without the consent of the United Mine Workers of America unless it was mined protected by guns and at the risk of destruction of life and property. Is this a serious situation? The dangers from combinations of capital are mere possibilities, but the results of the fuel monopoly are actual.

We are not left to conjecture. The facts are before us. The United Mine Workers have created a monster monopoly. They did shut up the anthracite mines for more than five months. They taxed the bituminous labourers and all labourers over whom organised labour had control to support the strike. The owners of bituminous mines, some in self-defence, others in the hope of gain, contributed freely to the strike fund. The public contributed freely. More than three million dollars were raised to carry on what they called the industrial war. With what result? The price of both anthracite and bituminous coal more than doubled. The supply was inadequate. The public was suffering not only from the high price, but from the scarcity of coal. Industrial operations closed down and men were thrown out of employment. All over the land, except in the districts that could be supplied by the great anthracite coal companies, the poor, the honest workman and the well-to-do suffered for want of fuel. In the middle of winter, in a land of plenty, this gigantic monopoly had the power to create a scarcity of fuel and bring distress upon a whole nation.

It is seldom that the violation of sound economic business rules so quickly brings with it such a series of disasters. How far the public will take to heart the lesson that has been taught is, of course, as it always is, an unknown problem. But this Commission represents the dignity which ever must uphold law and order, the justice that is inherent in righteous judgment, and the wisdom that can respect the progress and mighty achievements of our social and business conditions which have produced such marvelous prosperity. And, holding fast to that which is good, it will be slow to recommend a new order of things that may lead to the dire results which a six months' trial has already produced.

But someone will say, "Oh, all these direful results might have been averted by you operators." How? By a surrender to unjust demands. Yes; the evil day could have been postponed.

Let us not deceive ourselves. Men charged with the management of property, conscious of no wrong-doing, believing they are dealing justly with their employees, ought not to surrender at the dictation of labour leaders whose reputation and subsistence depend upon their success in formulating impractical demands, and thereby stirring up strife. The record shows that an honest effort was made to convince the United Mine Workers that their demands were unjust.

The anthracite coal trade has for fifty years been a most perplexing problem. It has, perhaps, aroused greater expectations and caused more disappointments than any large business enterprise in the country. To the untutored mind it seems so easy to dig coal and to sell it at a profit. But to the men who have given their best thoughts and years to the problem it becomes one of the most complex of all industrial problems. Indeed, when I look back over more than thirty years of my own connection with the Reading system and recall the struggles of the system and the able men who have gone before me, it seems that their labours were like those of Sisyphus.

You know that coal cannot be well stored. Bituminous coal cannot be stored in very large quantities because it is apt to ignite. Anthracite coal can be stored, but the cost of storing it is very great. We have made some experiments as to storing coal and picking it up again. The cost, with the breakage and the lowering of the grade of the coal, amounts, as near as we can get at it, to twenty-six cents a ton. We have found that we cannot store coal and

pick it up under a less charge than that, and then the facilities must be extraordinary. But we have never been in a condition to get large storage yards. We have tried it. In the past this has been the condition of the trade:—

In the summer months people do not want coal. The great consumption of coal is in the domestic sizes, although manufacturers, of course, consume the small sizes of coal during the summer months, as well as in the winter. The result has been in the past that during the six months from April to the first of October we could not operate our mines fully, because there was no market for the coal. The inconvenience was enormous. The cars of the transportation companies were out of use, their locomotives were out of use, and all their crews were idle. They lost the investment not only of all their capital, but they were compelled to keep up their equipment, so that in the six months of the year when there was an active demand for coal the whole system would be congested, and the movement of the coal itself by the railroads was accompanied with great additional expense.

That condition we have tried to meet in various ways, and it has resulted undoubtedly, at times, in depriving the miners in the coal region of steady work. No one has ever denied that was an evil. The trouble in the anthracite coal regions in the past was not the rate of wages. The only ground of complaint these men could have was in the fact that by reason of market conditions it was impracticable to carry on colliery operations every day in the week or in the month, and thereby their ability to work six days in the week was taken from them. Although the *per diem* wages were fair, when men could work only three days a week the annual result was not satisfactory. But it was a condition that could not be met except by the enlargement of the markets.

When the present exceptional prosperity came upon us in 1898 and 1899, there was a demand for coal, and the men, instead of being given work three days, were enabled to work five and six days. Then came 1900, in which the demand was still great and increasing, so that both the operators and the transportation companies were being taxed to their utmost to mine and transport the coal to the markets. Then came the disturbing element, the Miners' Union, and under exceedingly favourable conditions,—I mean favourable to them,—they succeeded in getting an organisation, and getting up a strike which resulted in a compromise of 10 per cent.

Let me show you how little they gained. At that time, and for years we had been operating in the Schuylkill region under the sliding scale, a system of profit-sharing whereby when the price of coal increased, the wages increased,—the only fair and honest way in which to increase or decrease wages, so that the men shall share in the prosperity and learn to practice economy during periods of depression. The only objection made to the sliding scale was that it had not a minimum basis. Perhaps it ought to have had. I shall not now review that situation, but simply point out this, that if the Philadelphia & Reading Coal and Iron Company had accepted the Mine Workers' proposition of 10 per cent., as was done in the other regions, the men would have received less money than under the sliding scale. Because we felt that only a limited number of our men belonged to the United Mine Workers, we voluntarily increased in 1900 from 10 per cent. to 16 per cent., so that the men in the regions would receive the same wages they would have received under the sliding scale. It is possible on existing wages in the region for any man to make average wages equal to those paid in any other industry in the United States. If this sliding scale had not been abandoned, the mine workers would, under the increased price of coal, have been entitled to the benefit, and their wages would have been considerably increased in the past few months.

Roundly, any one per cent. increase in wages will cause an advance of two and a half cents on a ton of domestic sizes of coal. In addition to this, we

must not overlook the fact that if wages go up, then materials and supplies necessarily participate in the increase, and the general cost of mining coal is increased. The proportion of wages on a ton of coal is about $1.45 to $1.50. This represents the average cost under the present conditions of producing a ton of coal,—that is, the wage labour of producing a ton of coal,—and from 40 to 45 cents represent the supplies that go into the cost of the coal. Our coal roundly costs us about $2 to put on the car, and $1.45 to $1.50 represent wages.

The production of coal is one of the few industries in which there are three parties to be considered:—First, the operator, because he controls the business,—for the present at least; second, the workmen; and third, the consumer. In most industrial operations the consumer is only indirectly interested. He need not purchase the things if their cost is too great; but coal he must purchase. If he is a manufacturer, he requires it for power, and everyone needs it to cook his breakfast and warm his home. The price cannot be arbitrarily fixed. It is undoubtedly true that the mine workers must receive an adequate compensation, measured by like wages under similar conditions in other industries, and, I take it,—with some hesitation,—that the operator may be permitted, under a normal condition of society, to have a little profit on the capital and work he bestows in the business. If the anthracite mine operator fixes the price on anthracite coal so high that the manufacturer cannot use it, the manufacturer will do one of two things,—purchase bituminous coal, or, if in the locality of his manufactory that cannot be had to advantage, he will abandon the site of his manufactory and go to a more favoured locality where fuel is cheap and plentiful. In this problem of manufacturing, fuel is the foundation of everything. It, therefore, becomes a business duty and a business necessity to see that manufacturers are given coal at a reasonable price. If they cannot get it, they will be driven out of business. And if they are driven out of business, then the sources of trade for the railroads fail.

These are problems that captains of industry in these days must consider, and must daily consider,—how to increase the wealth of the community they are serving by increasing its prosperity,—because only in that way can they add to their revenues; how to return to their stockholders a just payment for the money they have invested, and how to give honest wages, fair and full wages, to the men they employ. These are burdens. You may think they are light; but to a man who is charged with responsibility they become terrible realities.

What, then, can be done practically? If you increase wages, what will you accomplish? If they are too low, increase them; it will pass on to the consumer, and that consumer will be the rich and the poor. If they are just, then let them alone.

What evidence have you that they are unjust? We were led to believe, when an attack was made upon the horrible conditions in the anthracite fields, that a condition existed whereby men were being oppressed. Attention, however, has been called to the fact that on the basis of wages supposedly being paid in the anthracite regions, the advance claimed makes less than the wages that have actually been paid.

Now, that the wages are fair we demonstrated by a number of things to which I want to call your attention. You will remember that it has been said that one of the evils in the coal region is that there is too much labour there. What does that indicate? Why, that labour there is attractive. There is plenty of work in the United States, and those men could get employment elsewhere. Are you going to increase the rate of wages, and attract still more people there to sit down and wait in the hope of getting enough money in a day to support them for a week? Will you improve the congested labour condition in the anthracite fields by raising the price of wages so as to attract all unemployed labour into that field and bring on a worse condition of things?

Remember how easily the trade of anthracite mining is acquired. There is no apprenticeship, such as in ordinary trades; no such conditions as many of us went through when, as boys, we served as apprentices, working night and day to acquire a trade, with little or no remuneration.

Under the mining laws of Pennsylvania a man, of course, must be a certified miner. But each year hordes of strong men come from over the sea. They come as labourers and obtain work in the mines. They are paid larger wages than they ever dreamed of in their own countries,—from $1.50 up to $1.75 or $2 a day. They work as labourers for two years in the mines receiving this pay, and at the end of two years they can become certified miners. This is the only apprenticeship they serve. After that they can go into the mine early in the morning and drill their hole and blast their coal, and at eleven o'clock walk out to smoke their pipe and enjoy leisure.

It is no skilled trade. There is no apprenticeship such as prevails in the arts, —with the carpenter and the mason and the bricklayer and all artisans, and, above all, the machinist, who has to devote years to acquiring great skill. Are these men who work five and six hours a day, and earn the sums of money we have shown you that they do earn, to become public pensioners at the expense of every honest workingman in this city and in all the cities of the seaboard? Shall he be made to buy coal to keep himself warm and to cook his meals at an unfair price?

If there is any sociological question involved here it requires you to consider most carefully whether, in trying to do some favour to the coal miners in the anthracite regions you are not only going to work injustice to the operators, but you are going to do a wrong to every consumer of coal.

I have heretofore called attention to the sliding scale. I intended to discuss the question of eight hours a day; but I will let that go. Enough has been said upon that subject. I do not believe in the theory. There are some trades where eight hours are enough, but there ought to be no limitation on work in the collieries. If the breaker time is reduced to eight hours per day, the output of coal would be so restricted that the cost of coal would be increased enormously. Of course, the answer would be, "Build new breakers and sink new shafts." That is easily said. Expend another half million dollars at each colliery; and then the public would have to pay the cost. It is one of the things that you cannot help. If you are oppressed in one direction, and the price has to go up, the public is the forgotten man; but there is where it falls all the time. The consumer pays for it. And those of us who stand up to protect the consumer, who represents the average man in the community, are always to be treated as merciless, tyrannical men.

That brings me to say one word in defence of our own companies. I submit that the companies I represent, the Philadelphia & Reading Coal and Iron Company and Lehigh & Wilkesbarre Coal Company, have suffered the most at the hands of these people, in that a number of our collieries are destroyed. Where is the evidence of our wrong-doing? What have we done? Have we ill-treated our men? Have we wronged them in any way? Is there any testimony here to cast a shadow of doubt on the integrity and the honesty and the fairness of these companies in dealing with their men? Who is there that will dare to say, or has said, that the humblest man in our employment has been refused redress or consideration of any complaint?

Superintendents tell you that they hear every complaint and treat it justly. Such is their instruction. This company is too big to be dishonest. It means to deal fairly with all men. It means it because its management is honest and its policy is honest. And I protest that nothing has been more unfair than to drag us here into a controversy of this kind, without showing that there was any wrong done, or that anything in our system needed to be corrected.

Now, then, what is the practical suggestion that I have to make? I would gladly see a return to the sliding scale.

For some reason or other the sliding scale meets with little favour among labour leaders. You are asked to fix the price of coal practically for three years. I am not a prophet. I do not know what the business conditions of the next three years will be.

I can hope that the general prosperity of the country will continue so that wages can be even increased. But I know, as a business man, that I am not willing to commit myself to the payment of wages for three years based upon the existing condition of things. I do not know the day nor the hour when a break may come, and, as a cautious man of the world, charged with grave responsibilities, I want some system adopted that will work like the governor on an engine and regulate the speed at which we go.

I want to say that, while it is entirely true that some of the men have not been as prompt as we wished them in working on holidays, and some of them have shut down the breakers at one colliery and another to go to a funeral, and sometimes in times of great distress they would not work when we thought they ought to work, I will say that, taking the whole situation through, the behaviour of men in our companies since the strike is over has been admirable. They have rendered efficient work, and produced all the coal which, under the circumstances, could be produced, unless they had worked on these exceptional holidays, and while that would have been desirable, you cannot ignore the conditions and the traditions of people. These foreigners come here with many holidays. They have been accustomed to observe all their holidays. I am not going to find fault with a man who keeps his native holiday, even though it does deprive us of a little coal. There are some things that must be allowed to individual freedom, and this is one of them.

Now, what is my proposition? That the rate of wages now paid shall be the minimum basis for the next three years.

That from the first of November to the first of April, 1903, all employees, other than contract miners, shall be paid an additional five per cent.

That on and after April, 1903, for each five cents in excess of $4.50 per ton on the average price realised for white ash coal in the harbour of New York, on all sizes above pea, wages shall be advanced one per cent.; the wages to rise or fall one per cent. for each five cents increase or decrease in prices; but they shall never fall during the next three years below the present basis.

Now, before I give the result, let me just explain what that means. We will take the risk of guaranteeing for three years the present basis of wages. I say risk. We take a great risk in doing that. It means that the price of coal must be kept in New York harbour $4.50, or otherwise we are carrying on operations at a loss. We are willing to take that risk, and to pay, in addition, one per cent. increase in wages for each five cents increase on coal, taking the prices at New York harbour, which eliminates all calculations, as a basis.

The average price for each region to be ascertained by a competent accountant, to be appointed by Judge Gray, chairman of the Commission, or by one of the United States Circuit Judges holding courts in the City of Philadelphia, the compensation of the accountant to be fixed by the judge making the appointment, and to be paid by the operators in proportion to the tonnage of each mine; each operator to submit a full statement each month to said accountant of all the sales of white ash coal, and the prices realised therefrom, f. o. b. New York, with the right of the accountant to have access to the books to verify the statement.

ELECTRIC TRACTION ON STEAM RAILWAYS

By Alton D. Adams

ELECTRIC traction has proved its superiority for distributed loads, but concentrated loads are still hauled almost exclusively by steam locomotives. Where cars are to be moved along a track at frequent intervals, as in the public streets or between nearby cities, electricity is the cheapest power. Where, on the other hand, trains must run between distant points at intervals of, say, several hours, steam traction is thought to give the highest economy. The difference between supply to distributed and to concentrated loads is the main barrier to electric traction on steam roads.

Consider, for example, a railway, one hundred miles long, on which a car, or cars, requiring 2000 horse-power must be kept in motion. If twenty cars, taking a maximum of 100 horse-power each, may be employed for the traffic, the electrical conductors and distributing apparatus will never be required to deliver more than 100 horse-power at any one point on the railway. If, on the other hand, the entire traffic on the line must be concentrated at any one time in a single car or train, then the electrical conductors and distributing apparatus must deliver the full 2000 horse-power at each and every point along the railway in succession. In other words, with the concentrated load the capacity of the distributing apparatus at each point on the railway must be twenty times as great as the capacity when twenty cars are used to haul the same total load.

The application of electric traction on steam railways may thus involve a prohibitive capacity in, and expense for, distributing apparatus, unless the traffic can be divided among many separate cars or trains following one another at frequent intervals.

But it is quite clear that through passenger traffic, and more especially through freight traffic, cannot be economically carried on by a large number of separate cars or small trains. This is so because the expense of operation per train, especially as to labour, goes up much less slowly than the size of the train or the weight of its load. In recognition of this fact the number of cars and weight per train on steam railways, particularly in freight traffic, have long been on the increase. According to the reports of the Interstate Commerce Commission, the average number of tons per freight train in the United States was 175.12 in 1890, but stood at 270.85 in 1900.

If electric traction is to be substituted on steam roads, it seems certain that the electrical equipments must handle long, heavy trains some hours apart, as steam locomotives do now. The vital question is whether the necessary investment in electrical equipment will be prohibitive. It may be assumed for present purposes that the first cost of generating stations and of electric locomotives or car equipments is not a serious obstacle to electric traction. The discussion must, therefore, turn on the cost of conductors and distributing apparatus between power stations and the railway lines.

It is obvious that power stations must be far enough apart so that with concentrated traction loads and infrequent trains each station may work during the greater part of each day. Taking the railway 100 miles in length, let it be assumed that trains which require 2000 horse-power each will pass over it, one at a time. Let the power station for this railway be located at one end, so that the distribution apparatus must deliver 2000 horse-power at successive

points along the line to the end, 100 miles distant. Can any known system of electric traction be applied here with a permissible investment in apparatus for the distribution?

The most common electric traction system, in which continuous current is generated at about 600 volts in the power station and is distributed over line conductors and the rails to the car motors, can have no application in this case, because the weight and cost of such conductors for a transmission of 100 miles are absolutely prohibitive.

To avoid excessive cost of line conductors the system with alternating current, developed and transmitted at high voltage to sub-stations along the line of the railway, is being extensively applied in the United States. From these sub-stations continuous current at about 600 volts passes over the trolley wire and rails to car motors. Each sub-station, like a generating station of equal voltage, can serve with economy only a few miles of track, say five at most, in each direction from it. With distributed traction loads this system works well, because each sub-station finds its load of cars on the section of track nearest to it, and the capacity of a sub-station need be only a small fraction of that at the generating station.

If this system, with high-voltage transmission and continuous-current sub-stations, be applied to the railway 100 miles long on which moves a single train, the capacity of apparatus at sub-stations becomes excessive. Even if only ten sub-stations are employed, each operating the train while it is on ten miles of track, the combined capacity of sub-stations must be 20,000 horse-power. This capacity results from the fact that each sub-station must operate the 2000 horse-power train over a distance of ten miles. Neglecting, for the moment, the cost of high-tension transmission lines to sub-stations and low-tension feeders to trolley wire and track, it can hardly be expected that steam railway managers will install a generating station of 2000 horse-power, and sub-stations of 20,000 horse-power, in order to operate a 2000 horse-power train over 100 miles of track.

On the Continent of Europe quite a number of electric railways are being operated entirely with alternating current used in induction motors. The usual practice is to develop the current at any high voltage desired for the transmission, and then lower it to between 400 and 750 volts at transformer stations located at intervals along the railway. Such transformer stations do not require the services of attendants, as do sub-stations that deliver continuous current, and they save the cost of rotary converters.

From the transformer stations low-tension feeders pass to the trolley wire and track in a way similar to that where continuous current is distributed. In order to cut down the cost of low-tension feeders as much as possible, these transformer stations are usually located at much shorter intervals apart than sub-stations with rotary converters would be. Thus, in the United States rotary converters for railways are seldom placed less than ten and often as much as fifteen miles apart, while on the Burgdorf-Thun Railway, in Switzerland, a good example of traction with induction motors, there are fourteen transformer stations on a line only twenty-five miles long. The stations are thus less than two miles apart.

On the railway just named the voltage at the generating station is 16,000, and the transformer stations reduce this to 750. During each day twenty-four through trains pass over the entire length of the line, and there are also several local trains on a part of the line. Each train requires 225 kilowatts, and each transformer station has a capacity of 450 kilowatts, so that two trains can be operated at once on each section of track. Plainly this railway presents a case of distributed traction loads, so that the total capacity of transformers can be kept within permissible limits.

How would this system with induction motors at 750 volts and transformer stations work out on the 100 miles of railway with a single 2000 horse-power train? Each transformer station must

have a capacity of 2000 horse-power in order to operate the train over a section of the railway, and the number of stations, with one for every two miles of line, is fifty. To operate the 2000 horse-power train on this basis requires, besides the generating plant of that capacity, transformers to a total of 100,000 horse-power. Neglecting again any question as to the cost of the high and low-tension lines, it is evident that good management will not replace a 2000 horse-power steam locomotive with a stationary steam plant of like capacity plus 2000 horse-power in electric generators and 100,000 horse-power in transformers.

On the electric railway connecting Lecco, Chiavenna and Sondrio, in Northern Italy, the number of transformer stations is made relatively small by the distribution of current at 3000 volts from the transformer stations to the three-phase motors on the cars. The total length of this railway is 65 miles, and there are twelve transformer stations, so that their average distance apart is 5.5 miles. Each transformer feeds a definite section of the line, and each passenger car carries motors with a capacity of 600 horse-power. From this capacity it may be inferred that cars are run at rather short intervals. The generating station of 7400 horse-power works at 20,000 volts, and the transformer stations reduce this to 3000 volts, current at this pressure entering the car motors. Each transformer must operate one train on its section of the track, and may be obliged to supply two trains.

If this system with distribution from transformers to motors at 3000 volts is applied on the 100-mile railway with a single 2000 horse-power train, what must be the capacity of electrical equipment? With one transformer to each five miles of railway, twenty transformers will be required. As each transformer must have a capacity of 2000 horse-power, their total capacity is 40,000, and to this must be added 2000 horse-power in dynamos at the generating station besides the steam plant there. It will hardly be contended that the advantages of electric traction warrant the substitution for a steam locomotive of 2000 horse-power of dynamos and transformers aggregating 42,000 horse-power plus a stationary steam plant with capacity equal to that of the locomotive.

From the examples given it is obvious that the systems of electric traction thus far used to operate comparatively small and frequent cars or trains cannot displace steam locomotives for through freight and express service, because of the great cost of distributing apparatus. But radically different systems of electric traction are at hand. In 1899 and 1900 tests were made on the Teltow road, in Germany, of a system in which three-phase current at 10,000 volts was delivered to the cars and there transformed to about 650 volts for the motors. Following these experiments the fifteen-mile railway from Zossen to Marienfeld, with 10,000 volts on the trolley line and a transformer on each car to reduce the pressure for its motors, was constructed. The motors on each car of this railway have a normal rating of 1000 horse-power, and can be worked up to 3000 horse-power. Three-phase current and induction motors are in use on this line.

At Oerlikon, Switzerland, there is under construction, if not already completed, an electric locomotive of 700 horse-power that will operate on a railway where single-phase current will be distributed at 15,000 volts from stations seventeen miles apart. On this locomotive the 15,000-volt current will be transformed and then converted to continuous current before delivery to the motors.

In the United States, in Michigan, sixty miles of railway, recently completed, will be operated with cars that take single-phase current from the trolley wire and transform to low pressure for the motors.

The important feature of these two last-named systems for application on steam railways is the location of transforming and converting apparatus on each car or locomotive instead of at intervals along the track.

The importance of this distinction is at once apparent if equipment for the 100-mile railway with a single train requiring 2000 horse-power is considered. If the voltage selected is high enough to give economical transmission at a distance of 100 miles from the power station, the line conductors represent the only distributing apparatus, aside from that on the train. With single-phase or induction motors driving the train directly, the capacity of transformers is only 2000 horse-power. If continuous-current motors are employed for the traction, then 2000 horse-power in alternating motors and a like capacity in rotary converters must be added to the train equipment.

Single-phase current of 2000 horse-power and 20,000 volts, delivered to a train at one end of the 100 mile line from a generating station at the other end, over a copper trolley wire half an inch in diameter, would represent a loss of nearly 8 per cent. in the trolley wire. Assuming that the track would just equal the trolley as a conductor, then the maximum loss in trolley wire and rails would be just under 16 per cent. with the train 100 miles from the generating station. The loss of transmission increases from zero to its maximum as the train moves away from the station, so that the average loss would be 8 per cent.

With the system just described, a 2000 horse-power steam locomotive may be replaced by electric motors of 2000 horse-power and transformers of like capacity on the train, a stationary steam plant and dynamos of 2000 horse-power, and 100 miles of the trolley wire named. Whether the advantages of electric traction warrant such a change cannot be considered here. Certain it seems, however, that electric traction can displace steam locomotives for through traffic only if each train carries its own sub-station.

THE PALACE QUAY AT ST. PETERSBURG

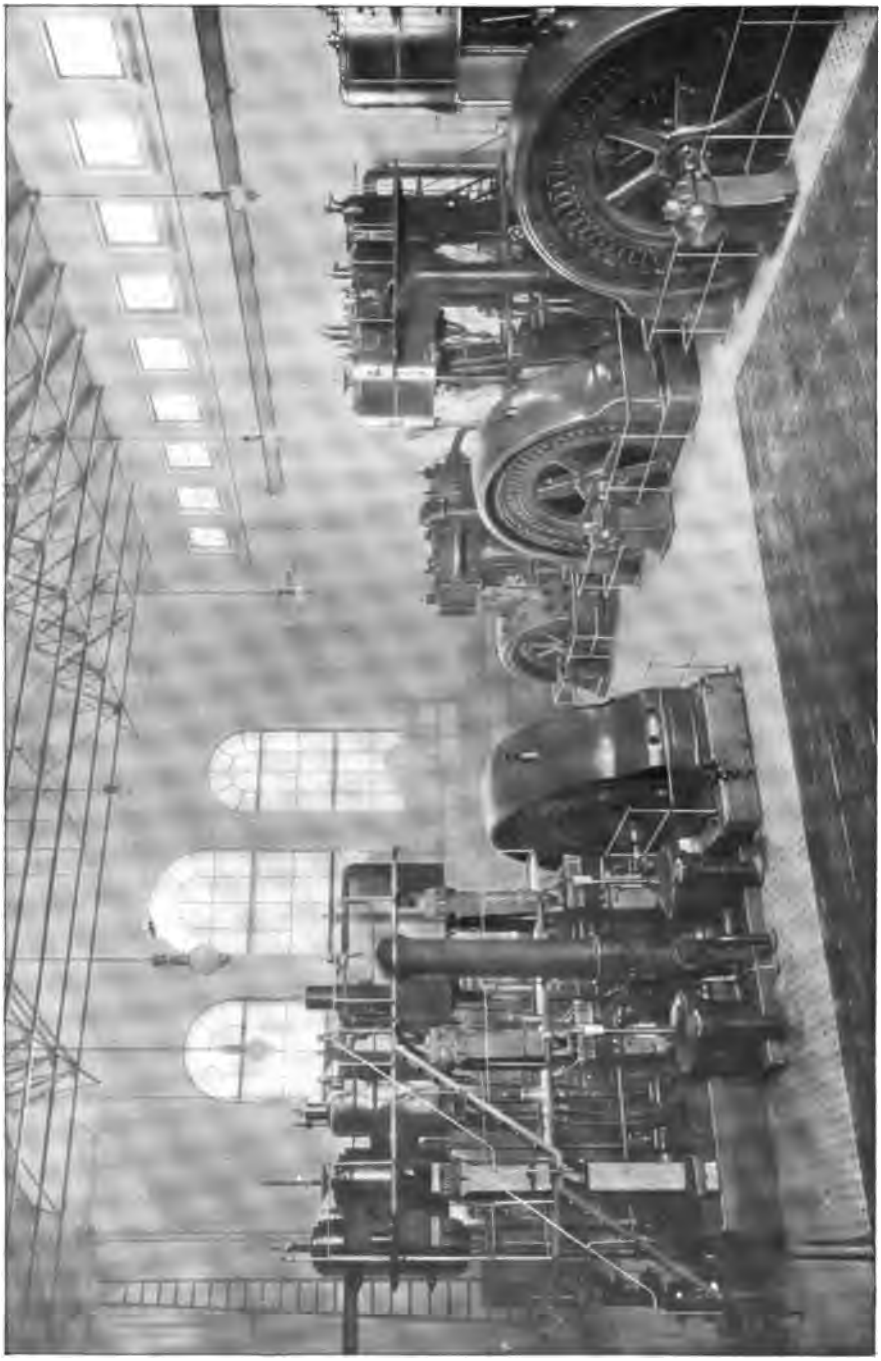
ELECTRICAL DEVELOPMENTS IN RUSSIA

By Thomas E. Heenan, Odessa, Russia

UNTIL recent times, the electric industry has made extremely slow progress in Russia. Unfavourable circumstances have combined to impede the industry and prevent it from reaching the level found in other countries. One of the principal causes of this lack of development was the absence of schools in which to educate electricians. Foreign engineers and specialists prefer to have recourse to materials and apparatus made abroad, of which they know the value, rather than to try to build factories and works in Russia for the production of the articles required by them.

Of late, however, as told by the writer in a recent consular report to the United States Government, the government, private companies and individuals have opened special schools for electricians; and, in addition, the special art and artisan schools have introduced electro-technical courses. The influence of these special schools and courses has not been slow to make itself felt, and of recent years electric industry has made immense progress. Many towns and cities are lighted by electricity, and electric tramways are numerous. Nearly all of the large factories and industrial establishments have adopted electric lighting and have applied electricity to the distribution of motive power. Electric energy has also been utilised in mining enterprises, particularly in the south of Russia. The use of electricity in the extraction and refining of metals, as well as in certain electro-chemical works, is now well developed in Russia. With the increased and varied applications, the demand for apparatus has grown enormously, and electric supplies of all kinds now find a large sale.

In response to this demand, workshops and factories have been established which produce more particularly the accessory supplies and conductors. There are but two factories in Russia which turn out dynamos and lamps, and in consequence most of these are imported. Germany and Switzerland furnish the largest number; next comes Great Britain, and then follow the United States, France, and Belgium. Statistics on the subject are not obtainable at the



THE INTERIOR OF A ST. PETERSBURG ELECTRIC LIGHT CENTRAL STATION

A PANORAMA OF MOSCOW

present time. It is possible, however, to estimate approximately the situation of certain branches of the electro-technical industry in Russia, and this estimate is undoubtedly below the actual condition.

ELECTRIC LIGHTS

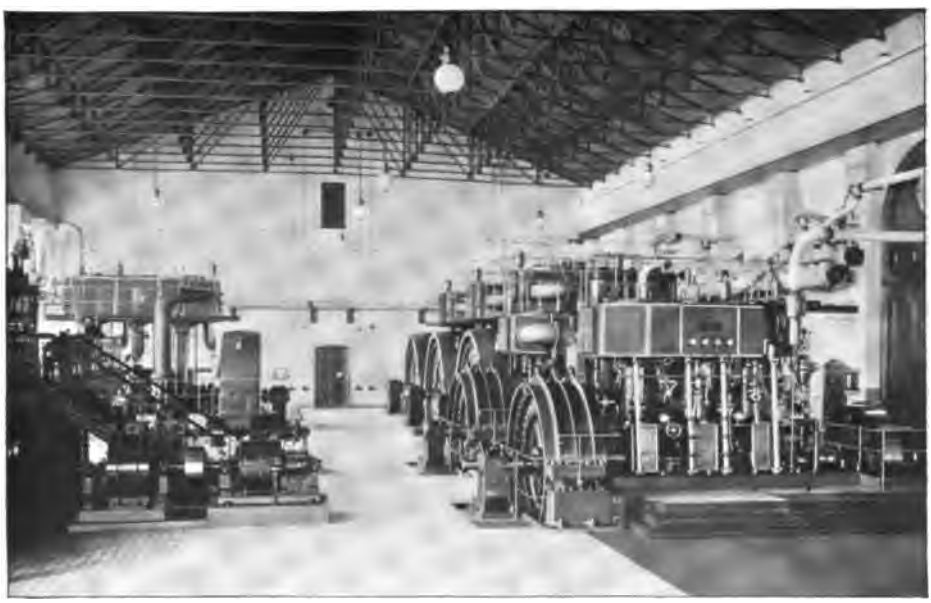
A few years only have passed since such cities as St. Petersburg and Moscow began to have their streets lighted by electricity. At present there are more than fifty towns which employ the electric light, and many other places are erecting the necessary apparatus. The rapidity with which the use of electricity has spread at St. Petersburg will serve as an example of the popularity of this manner of lighting. The first central station was installed in the city in 1881. The power of that station was about 250 kilowatts. Until 1885 there were only a few stations opened, and the power increased very slowly. After that year the power of the stations and their number grew rapidly, and in 1898 there were 169 stations, with a capacity altogether of 29,000 kilowatts. In 1898 and 1899 three additional central stations were constructed in St. Petersburg, and at the present time the power of all the central stations taken together (exclusive of the private stations) reaches 15,000 kilowatts. Work near completion will raise the power at these stations to 30,000 kilowatts. The number of private stations is about 300, and these have a total capacity of more than 39,000 kilowatts.

St. Petersburg is lighted by means of arc lamps on the principal streets and by incandescent lamps on the less important ones. In addition to the arc lamps on the streets, there are about 300 lamps fed from private stations. Electric motors of a combined capacity of about 4500 kilowatts, have been installed. In many of the private stations

storage batteries have been put up, and their capacity exceeds 50,000 ampère-hours. The number of dynamo machines erected at these stations is over 500. As a rule, the current is continuous. Steam engines are principally employed, but gas and petroleum engines are also in use. All of the large stations work with alternating current, and one of them uses the triphase current. The greater part of the wires is underground, being disposed in armoured cables. Overhead conductors are used at only a few stations. The aggregate length of the network is over 625 miles. The tension is from 2000 to 3000 volts.

In Moscow and in other towns, both large and small, particularly those situated in the industrial region, the use of electricity has made no less rapid progress than in St. Petersburg. At the beginning the stations constructed were almost all for continuous current, but in the later ones the preference was for alternating current. The distributing system is sometimes underground and sometimes overhead.

Electricity is also coming largely into use for tramways. The first electric tramway built in Russia was the one at Kief, which dates from 1893. In 1898 forty-five cities had constructed such lines, their length exceeded 312 miles, and nearly 10,000 kilowatts were in use for the motors. The number of motor cars was about 300, and there were many cars without motors. The total length of wire for the electric tramways in St. Petersburg is estimated at 1875 miles. Both overhead and underground conductors will be used, and, on the principal streets, storage battery traction. Nearly 400 motor cars will be in service, and 300 without motors. Other cities also contemplate the employment of electricity on a large scale, and plans are under consideration for its use on the great railroads of Russia. These projects include the construction of an electric railroad to connect neighbouring towns on the western frontier of Russia, and the establishment of a road to cross the Caucasus Mountains, between the town of Suhkum and one of the stations of the Vladikavkas Railway. For this latter road it is proposed to utilise water-power from the mountain streams. Electric traction is already in use on the



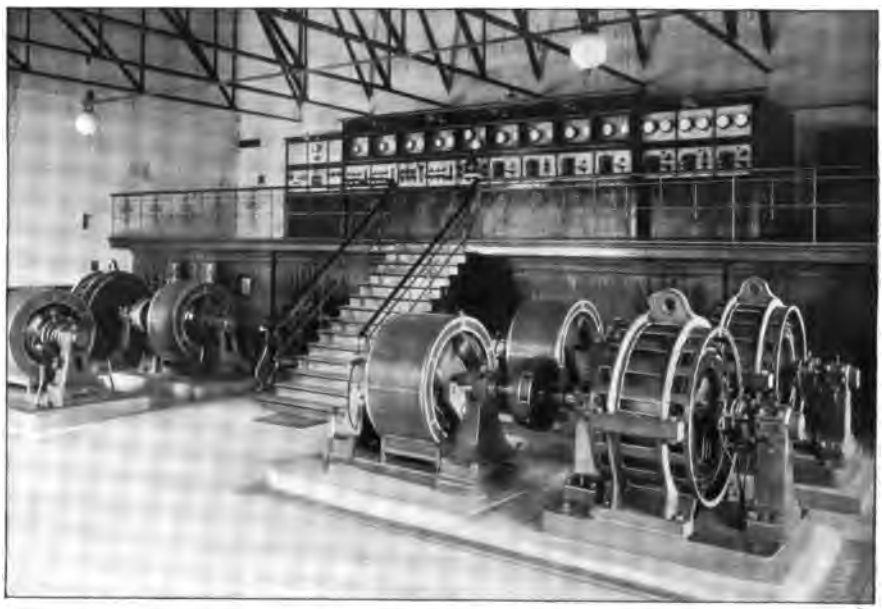
ONE OF MOSCOW'S EARLY ELECTRIC LIGHT STATIONS. EQUIPPED IN 1886 BY MESSRS. SIEMENS & HALSKE, OF ST. PETERSBURG

THE FIRST ELECTRIC STREET RAILWAY AT MOSCOW

ANOTHER VIEW, BOTH SHOWING ARTISTIC OVERHEAD LINE SUPPORTS AND THE USUAL CONTINENTAL BOW TROLLEY

railroads serving large factories, in the mining industry, and in other enterprises.

The use of electricity for the distribution of motive power is spreading, and to-day all of the machine works of Russia have adopted this method. Enormous central stations have been erected at places where such factories exist; for instance, at the Kolomna machine shops, at the works of the Sormovo Association, at the Putilov works, and many others. All of the larger grain elevators on the Vladikavkas Railway and on the Moscow-Kazan Railway are supplied with electric motors.



TRANSFORMER STATION OF THE FIRST ELECTRIC RAILWAY IN MOSCOW

Up to the present electricity has scarcely been used at all for the transmission of energy for great distances. Projects, however, are under way to utilise the waterfalls of Marva and Imatra. The Russian Government has granted a concession to a company to supply power to St. Petersburg from the Volhav rapids. The estimated cost of the enterprise is about $14,000,000 (£2,800,000). It is said that the power to be transmitted will equal 150,000 kilowatts, and the maximum transmission distance is 188 miles. The company has undertaken to provide the public lighting of St. Petersburg gratuitously, and hopes to furnish current to individuals at about half the price hitherto charged in similar enterprises. The engineer of the scheme is a Russian named M. Dobrotvorsky. It is also intended to transmit electrically the power of the Dnieper cataracts.

THE ELECTRO-CHEMICAL INDUSTRY

The progress of the electro-chemical industry and of electro-metallurgy is interwoven with the utilisation of hydraulic power for current generation. For instance, there are even now several establishments which produce copper and refine metal by the electrolytic process. Such establishments exist in the Ural and the Caucasus. Thus, the works of Siemens Brothers, at Kedabeg, in the Caucasus, annually produce about 500 tons of copper. Many less important works in St. Petersburg, Moscow, and Nishni Novgorod utilise steam power for the refining of copper and impure copper waste by the electrolytic process. Some of these works

AN ELECTRIC PERCUSSION DRILL IN ONE OF THE COAL MINES OF THE BRJANSKER MINING COMPANY IN SOUTH RUSSIA

A TROLLEY LINE AT SHITOMIR

obtain as by-products other metals, such as lead and antimony. There are as yet very few special electro-chemical works in Russia; one factory near the Imatra rapids produces carbide of calcium, and other works for a similar purpose also exist. A large electro-chemical factory has been erected in the government of Kharkof for the production of caustic soda. Electric welding, too, is in use in a number of works.

ELECTRIC APPLIANCES AND MACHINES

It will be seen that the application of electricity has progressed in Russia, and that electric appliances will have a great future in that country. Russian factories cannot supply the demand, and the deficiency is made up by foreign firms which have their representatives here. It is true that Russian manufacturers produce many cables and insulated conductors. At St. Petersburg and Moscow there are a number of factories in this line and their output compares favourably with the foreign articles. The most important of these establishments are the Siemens and the Riben works. Nevertheless, cables in large quantities are imported from abroad, the home manufacturers not being able to supply the market.

Storage batteries are also manufactured in various towns in Russia. There are a number of establishments in St. Petersburg which produce accumulators of original design or after the best-known foreign models, such as the Julien, the Tudor, and others, and the importation is small. Such appliances as circuit breakers, commutators, rheostats, and the like, are also made in Russia, but not in quantities sufficient to supply the demand. Measuring instruments are scarcely manufactured at all in this country, although the demand for them is enormous, especially of late, since central stations have been constructed in a number of towns. These instruments are imported from France

THE WINTER PALACE AT ST. PETERSBURG

and Germany. The manufacture of porcelain insulators and of electric porcelain appurtenances in general is so largely developed in Russia as to completely satisfy the home demand, and no insulators are imported.

Incandescent lamps are not manufactured in Russia at present. An establishment formerly existed for the manufacture of these lamps, but foreign competition was so strong that the attempt was abandoned. The lamps are at present imported from Germany, France, England, Austria, and Sweden. Arc lamps are produced in this country, but only in limited quantities, and the greater number of those used are imported from Germany. Carbons for the arc lamps also are manufactured in Russia, though most of them come from abroad.

As regards electric machines, such as dynamos, motors, and transformers, they are manufactured by only one firm, —Siemens & Halske, at St. Petersburg. This is also the only firm in Russia which produces appliances required in electric traction.

One branch of the electro-technical industry is fully supplied by the home manufacturers, and that is the signaling and telegraphic apparatus in use on the railways. As regards telegraphic appliances proper, some are manufactured in Russia and some come from abroad, chiefly from Sweden and Germany.

It will thus be seen that the demand for electro-technical apparatus and machines in Russia is relatively but little satisfied by the home manufacturers, and the progress in the application of electricity for transportation, manufacturing, and domestic economy will undoubtedly enormously increase the market for foreign appliances. British and American manufacturers should have their share of this trade, and there is but one way to secure it,—that is, to establish branch houses in this country and place them in the hands of competent men. The Germans hold the field in supplying this country with electric appliances, because they are ever present and always patient; they study their customers, ascertain their financial condition, give long credit with reasonable interest, and employ men who are either German-speaking Russians or Germans born in Russia, who, of course, speak both Russian and German.

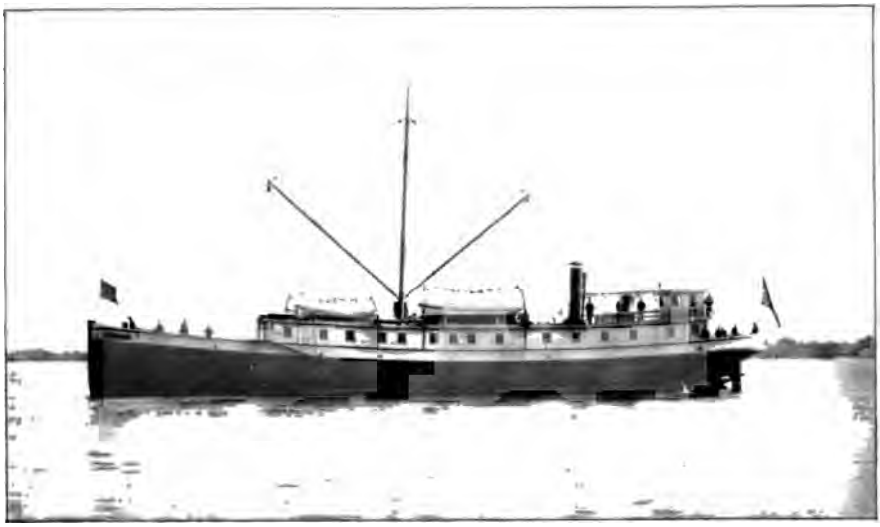
It will require more than a casual visit to Russia on the part of business men if they are to win a proper share of the future business to be done in electrical appliances. It is not too much to say that in no other branch of trade is there likely to be such material progress in Russia.

FLOATING DISINFECTING STATIONS

By Day Allen Willey

THE importance of disinfecting stations on shore and their value in preventing the spread of contagious disease which may be brought on vessels has been so impressed upon the United States Government that it has created a fleet of floating stations which include the principal features of those on land, while they have the advantage of being movable, so that they can go from port to port if necessary and use their appliances in connection with vessels in localities where cargo cannot be conveniently landed.

This sanitary fleet consists of schooners and barges which have been remodeled and filled with apparatus, as well as several steamers which have been constructed especially for the purpose. The latter include the *Sanator*, which is probably the most complete vessel of its kind yet constructed.



THE UNITED STATES DISINFECTING STEAMER "SANATOR"

A DISINFECTING BARGE

As this ship contains not only apparatus of the kind installed in the other craft, but some special equipment for disinfection, a description of its principal features may be of interest. The vessel is 161 feet long, 32 feet beam, and 12 feet in depth of hold, while it can be navigated in 8 feet of water. This allows it to enter shallow harbours. The material of the hull is oak, and the framework and planking are unusually heavy for the size, in order to sustain the quantity of machinery required and to give the vessel staunchness in a seaway.

The hold contains a compartment for the reception of materials to be disinfected. Into it open two disinfecting chambers, while it also contains a vat holding bichloride of mercury. The clothes or other effects to be treated are lowered through a hatch into cars which move upon tracks leading into

the chambers. The cars are provided with trays and hooks so that articles may be separated as desired, and are pushed into the steam chambers, which are cylindrical in shape, 16 feet long and nearly 5 feet in diameter. They are composed of an inner and an outer steel shell, forming a steam jacket closed by doors of ½-inch steel plate.

A VIEW OF THE INTERIOR OF ONE OF THE SANITARY BARGES, SHOWING THE FAN USED FOR DRIVING FUMIGATING GAS THROUGH PIPING TO DIFFERENT POINTS OF SERVICE, AND ALSO THE SULPHUR FUMIGATORS OR GAS GENERATORS

The chambers are built to carry a working pressure of ten pounds per square inch. They are covered with magnesia covering, and are fitted with a complete system of steam and exhaust pipes, drains, and traps. A steam exhauster is connected with both chambers, which is capable of producing in either a vacuum of 15 inches in less than a minute. The drainage is led through two steam traps to two drainage tanks under the hold floor, these tanks being emptied overboard by a steam ejector. Steam and vacuum gauges, safety valves and thermometers are provided, and reducing valves are fitted in the steam supply pipes to regulate the pressure. The steam inlet to the interior of each chamber is at the top, and a copper hood extending the whole length of the chamber is provided to prevent steam impinging directly on the goods being disinfected.

The period necessary for steam disinfection depends upon the material to be treated and other conditions, usually being from thirty to forty-five minutes. When the operation is concluded, the doors of the chambers are opened, the cars run out, and their contents removed through the hatch.

The generators for formaldehyde gas and ammonia gas, when either is to be used, are connected with the steam chamber, one generator being provided for each kind. Each generator consists of a horizontal, closed cylinder contain-

ing a steam coil and provided with necessary pressure gauges, safety valves, and pipe connections. The cylinder and pipes for formaldehyde gas are made of brass and copper, and those for ammonia of cast steel and iron. Each is connected with both steam chambers, the purpose being to use formaldehyde gas for a disinfectant in either chamber if it is filled with any materials which would be injured by steam. The ammonia gas is used after the treatment by formaldehyde gas, in order to neutralise the latter and prevent irritating effects on the mucous membrane of the attendants, from inhalation and contact with the goods treated. Either gas is generated by introducing into the generator the proper quantity of formalin or a strong ammoniacal solution, as the case may be, and applying heat by means of the steam coil.

The ship is also provided with four portable formaldehyde gas generators that can be taken into the cabins or compartments of a vessel alongside for disinfecting purposes, the compartments being tightly closed to prevent the escape of the gas.

In the forward hold compartment are the two sulphur furnaces, side by side. Each is built of steel with cast iron fronts, the dimensions being, — length, 10 feet; width, 3 feet; height to top of reservoir, 6 feet 6 inches. There is a fire-box at each end of each furnace. Over these are shallow cast iron pans to hold the sulphur. Dampers and baffle plates are provided to regulate the supply of air and prevent too rapid combustion. On the top is a reservoir in which the sulphur dioxide is collected. The smoke from the fire-boxes is taken by a pipe near the bottom to a smoke-stack leading up through the main deck forward. Pipes from the gas reservoirs connect with a fan belted to a vertical engine. This exhauster delivers the sulphur gas through a 12-inch galvanised iron pipe leading through the main deck to branch pipes extending fore and aft on both sides of the upper deck. On each of these branch pipes are three connections for special 6-inch sulphur hose, by means of which the sulphur gas can be taken into any compartment of a vessel alongside to be fumigated. The sulphur bins forward of the furnaces hold, together, 40 barrels of sulphur. A 2000-gallon steel tank for storing bichloride of mercury solution is located in the hold amidships. Above this, in the deck house, is a 40-gallon mixing tank with connections for steam and water, as well as a connection to the large tank below. The proper quantity of the chemical is mixed in the small tank and allowed to flow into the large

ONE OF THE SULPHUR FUMIGATORS

CHEMICAL STORAGE VATS AND FLUES FOR CONVEYING FUMIGATING GAS

ONE OF THE DISINFECTING STEAM CHAMBERS ON THE "SANATOR." A GAS GENERATOR ALSO IS SHOWN, ATTACHED TO THE OUTSIDE OF THE STEAM CYLINDER

ONE OF THE "SANATOR'S" COMPARTMENTS, SHOWING ONE STEAM CHAMBER CLOSED AND THE OTHER ONE OPEN, WITH ITS CAR DRAWN OUT

tank, into which has already been pumped a quantity of water sufficient to make the required solution. Near the tank in the hold is a horizontal duplex pump, with water cylinder valve guards and connections made of iron and the valves of rubber, it having been found that the bichloride solution acts less quickly on these materials than on brass. This pump has suction connections to the sea, the bilge, and bichloride tank, and delivers to the same tank, to the bichloride pipe system, or overboard. Its principal purpose is to take the solution from the tank and force it through the bichloride pipes to hose plugs located at the four corners of the deck house and to two hose plugs in the hold. By means of the 2-inch hose, and spray nozzles, the solution can be sprayed as a disinfectant in any part of the vessel itself, or in any part of a vessel alongside being disinfected. A bichloride vat is located in the "infected" compartment into which articles may be dipped for disinfection.

As already stated, some of the boats are merely hulks which have been altered for their present purposes, and are towed from point to point where their services may be desired. This type carries a crew of six or eight men. The steam required for disinfecting is furnished by a 40 or 50 horse-power boiler. One of the barges, however, is of about the same capacity as the *Sanator*, and, like the former, was constructed especially for this service. It is the largest of the fleet, the majority ranging between 127 and 156 feet in length. It is provided with boilers capable of developing about 250 horse-power, and is self propelling. It is provided with an electric light plant, and a ventilating system which will renew the air in the hold every five minutes if desired. In addition to the dis-

infecting apparatus it contains storage space for a large supply of the necessary chemicals, so that it can make an extended voyage if necessary, not only fumigating material taken aboard it, but transferring its gas to the holds of other vessels by means of the pipe connections already mentioned. Such is its capacity that the hold of a 5000-ton ship can be filled in two hours. In addition to the quarters for the crew of twelve men, temporary accommodations are provided for about forty persons in cases where the quarantine officers may deem it necessary to detain a ship's company for personal disinfection.

PNEUMATIC TUBE SERVICE

By Edmond A. Fordyce

THE mythology of the ancient Greeks and Romans represents the messenger of the gods as a young fellow whose heels are shod with wings through which the air became the medium of his flight in conveying the messages and commands of his imperial masters. In the sacred poetry of the ancient Hebrews the "wings of the wind" constituted the chariot of omnipotence in the swift execution of sovereign purpose and command. The ancient literature of numerous other early civilisations is replete with the same figure.

In our day the "wings of the wind" as messengers have passed from symbol to fact,—from mythology and poetic fancy to practical reality. The lithe, athletic Mercury, winging his swift course on the breast of a favouring wind with messages from imperial Jove to the lesser deities, has become a little cylindrical "carrier," darting away with the rapidity of a bird on the wing under the impulse of a confined and directed air current, carrying its message safely locked within against harm or loss, and after a brief period of swift flight delivering its charge at its appointed destination.

The art of pneumatic despatch tubes for the conveyance of messages, parcels, freight matter and even passengers in its theoretical aspect is over two centuries old. It is not the purpose here to treat of its early history and experimental development. It may, however, be noted that the art had its earliest development in Great Britain in the first half of last century, and the records of the British Patent Office for the twenty years between 1835 and 1855 show astonishing activity and interest among inventors in the art of pneumatic transmission of express and mail matter through closed conduits and tubes. The streets of London, Paris, and other cities of Continental Europe were the scenes of numerous early experimental pneumatic tube plants, most of which, though successful mechanically, failed because of financial difficulties.

One of the oldest of the United States patents relating to the art was granted more than thirty years ago to Mr. Alfred Beach, of New York. It provided for a tube system which contemplated the carrying of passengers in cylindrical carriages travelling in a 10-foot tube or conduit and designed to be driven by an air current at a speed largely in excess of modern express railway speed. The drawing of this old patent shows the car at a station, with doors in the walls of the tube and car thrown back and passengers leaving and entering the car. But the scheme did not go beyond the experimental stage, though it is but fair to say that the causes that proved fatal to its practical development did not so much reside in mechanical impossibilities as in the enormous expense and outlay of capital

which the construction, operation, and maintenance of such a plant would have involved. But in our day of gigantic engineering and financial operations initial expense constitutes no serious obstacle to an enterprise which can be subsequently made to pay fair profits on the capital invested; and if on its mechanical side the fuel energy required for the transmission of a given weight of matter a given distance by pneumatic tubes can be reduced below the amount used to accomplish the same by the steam locomotive or electric motor, we may yet see pneumatic transmission applied to the direct propulsion of vehicles for passenger service, as well as for mail and express service.

Undoubtedly the most extensive, and thus far the principal, service which the pneumatic tube art has rendered has been in transmitting money and memoranda of sales between the sales counters and the cashier's office in dry goods and other shops,—a mechanical convenience with which the public has grown so familiar that it is now regarded as an indispensable part of the equipment of every first-class retail establishment. And along with the development of the pneumatic store-service system has come the more tardy application of the same principle to the distribution of mail and express matter in large cities. Several of these have for a number of years enjoyed the benefits of rapid collection and distribution of mail matter through underground pneumatic tubes.

The earliest practical application of pneumatic transmission outside of shop and mail service was in the distribution of telegrams and telegraphic news matter. Prior to 1887 the Western Union Telegraph Company, in the United States, had established in New York a pneumatic service of its own for sending messages singly or in bundles between the branch stations and the main office, and for supplying the daily newspapers of the city with their associated press telegrams and special dispatches, these being sent in carriers through 1½-inch individual pipes leading to each point of collection and delivery.

In 1893 the City Press Association, of Chicago, out of patience with the slow and unsatisfactory delivery of telegraphic news dispatches by messenger boys, contracted for and installed beneath the streets of Chicago fifteen miles of the most costly and elaborately constructed pneumatic tubes ever put into service. These tubes connected the main office of the Western Union Telegraph Company with the offices of the association, the various newspaper offices, the City Hall, the Central Police Station, and several other points, and since that time messages that, in the hands of some dilatory messenger boy, used to keep the newspaper presses waiting for half an hour, are now shot to their destinations in but a fraction of a minute. This system, which was designed only after a thorough inspection of all the leading systems of Europe, is perhaps the most satisfactory of its kind ever installed, no expense having been spared to make it perfect in every detail.

Pneumatic tubes are coming to be regarded as an indispensable part of the mechanical equipment of large public libraries. In one of the earliest pneumatic transmissions of this kind the slips calling for the book, or books, desired were shot from the central distributing desk through pneumatic tubes to attendants at the stacks, the books themselves being sent to and from the delivery room by basket conveyors. Similar systems have since been installed in a number of large libraries, and constitute probably the most important and effective part of the time and labour-saving equipment of such institutions. As messengers, they do their work with all the celerity of the telephone,—and do it withal in perfect harmony with the spirit of silence that pervades the atmosphere of a library, which the telephone could not do.

The success of large-tube systems for the transmission of mail matter has led to an extension of such systems in express service for the delivery of parcels and packages from the retail shopping districts of large cities to the outlying residence districts. Through such large tubes merchandise and express matter may be sent, with but a few seconds or

minutes at the most consumed in the actual transit between the distributing and receiving stations. The immense convenience of such a speedy system of parcel delivery may be appreciated from the fact that purchasers in shops frequently find that their purchases have been delivered and are awaiting them long before their return home.

Of late years pneumatic tubes have come to be extensively adopted also in warehouses, packing houses, railway freight depots, and other similar places. In the case of warehouses and supply houses of all sorts the tubes are laid between the various buildings, and serve to connect the main office with the different shipping and receiving points of the establishment. Orders, requisitions, receipts, and all kinds of mail matter are sent through these tubes, dispensing with the services of messenger boys heretofore employed; and, what is more important, eliminating almost entirely the time element,—almost to the same extent, in fact, as the telephone and telegraph have eliminated it

Three of the largest American railway systems recently installed in connection with their freight depots systems of pneumatic tubes by which all freight receipts, way bills, checks, etc., received at the different doors, are dispatched to a central office, signed, and returned to the door of the warehouse from which they were received, thus permitting the teamster to get the goods without the necessity of going to the main office, waiting in line, and then returning to his waggon. It is, perhaps, impossible to estimate the time that is thus saved; but it would be no exaggeration to say that where business is heavy this pneumatic system saves from a quarter to a half hour of an employee's time in connection with each delivery.

In many large wholesale and supply houses the pneumatic messenger system is profitably employed to connect various floors and departments. Orders received at the main office are dispatched to the respective desks, filled, and the goods are sent to the shipping desk without the necessity of sending messengers from the different floors with the orders. One large manufacturing company uses the system for connecting different buildings of its plant, and sends blue prints, small tools, samples of material, etc., through the tubes from different departments, all connecting with a central office, something like a telephone exchange, where the goods are re-sent, if necessary, to other buildings or departments.

One large electric supply company recently installed a pneumatic tube line over half a mile in length, through which orders received at the main office are sent to the railway warehouse, and are filled and shipped from there. Previous to the adoption of the pneumatic tubes these orders were sent by messenger boys, a method which involved a considerable loss of time, and frequently a mistake or loss in the delivery of the order itself. In another large pneumatic messenger installation the system has dispensed with the services of fifteen messenger boys; and in filling orders for railway delivery from twenty to thirty minutes are saved on each order, which means that an order received twenty or thirty minutes later than formerly is now filled and gotten off on the same day the order is received, while before the adoption of the tube system these orders would frequently have to go over until the next day. Many large factories have put in pneumatic tubes between their main offices and their various departments for the quick transmission of orders, blue prints, and other paper memoranda, which have hitherto required the services of one or more messenger boys. In still other departments of the business and manufacturing world too numerous for specific mention air currents as messengers to replace the tardy, tired, and sometimes lazy feet of messenger boys and men are gradually coming into use. The old adage that "Time is money" was never truer than in the present day; and a system of messenger and express service that practically converts time into money, besides contributing an increased element of safety, is bound to meet with public favour and acceptance to an ever-increasing extent.

Current Topics

THE availability of magnets as lifting devices has been known, experimentally and practically, for many years. Some of the oldest treatises on electricity and magnetism give the lifting power of magnets as that weight which the armature of the magnet will sustain without falling off, and it was a common, but, to the audience, always wonderful, feature of the quasi-scientific lectures that were more in evidence half a century ago than they are to-day, to suspend heavy nails, bolts, and various other articles, from the poles of magnets. These were permanent or natural magnets, usually of the horse-shoe type. With the advent of electro-magnetism more pretentious experiments were devised, amongst others that of winding a cannon with insulated wire and sending an electric current through the wire, whereupon a cannon-ball would be drawn into instead of shot out of the cannon's mouth. One of the practical uses of a magnet, but to those immediately concerned a highly important use, is that in which it is sometimes employed to withdraw small pieces of iron from such out-of-the-way places as the human eye. Another use of the tractive force of magnetism on a much larger scale was that to which it was put by Edison in his magnetic ore separator, in which the ore, previously crushed to a fine powder, is dropped down a chute past the poles of powerful electro-magnets, in passing which the iron particles of the ore are deflected to one side while the non-magnetic stone dust continues undeflected down the chute. Still another instance of the employment of magnetism in a small way is that in which a magnetised tack hammer is used in the manufacture of strawberry baskets on a large scale in conjunction with a mechanical device which presents the tacks, one at a time and head up, to the operative, thereby greatly facilitating his work.

IT is a far cry from lifting a tack by means of magnetism to the lifting of massive iron and steel plates weighing four, six, and twelve tons by this same force, which is now done every work day in a number of large steel works. Electro-magnetism, of course, is utilised, the form of the magnet being usually rectangular for this work and presenting a flat surface to the plates lifted. The magnets are suspended by chains from cranes, and pick up the plates by simple contact and without the loss of time consequent to the adjustment of chain and hooks in the older

method. It is also found that the metal plates can be lifted by the magnets while still so hot that it would be impossible for the men to handle them. The ratio of weight of these magnets to the weight lifted varies with the machine; in some cases this ratio is 30. Thus, a magnet weighing 300 pounds will lift 4.5 tons. The magnet is operated by current from a dynamo, controlled by switches and rheostats, and one of the capacity mentioned requires about four ampères at 250 volts, or 1.34 horse-power. These magnets also have the advantage for this class of work that a number of them can be applied jointly to lift a heavier weight than one machine could lift singly.

IF one stops to think of it, however, there is nothing remarkable or novel in the foregoing applications of magnetism directly to lifting purposes. There is not a trolley car running the streets that is not, so to speak, being lifted along by magnetism, *per se*, as much as are the iron and steel plates in the case just mentioned. We speak of electric traction in the case of the trolley car, but we might as well speak of electric lifting in the previous case, for it is not until the electric current develops magnetism that the car moves or the iron plate is lifted. The electric current, *per se*, lights arc and incandescent lamps, heats electric furnaces, decomposes electrolytes, but does not directly propel a car or lift a weight. The rotation of the electric motor on the car is secured by the attraction or pull of one magnetic field upon another, the brushes of the motor being placed at such a point on the commutator that the magnetism set up by the current around certain armature coils of the motor does not correspond with the magnetism of the field magnet. The tendency, therefore, is for the armature to be pulled into a position where the respective magnetic lines of force of the two fields will coincide, and the armature being movable, while the field magnets of the motor are fixed, the armature turns; but the moment it does so, the armature coils which were carrying the current from the brushes slip past those brushes and another set of coils, whose magnetism is not in correspondence with the field magnetism, is brought into action, whilst the current and magnetism die out of the first set of coils. Hence the armature is again pulled around, with the result that still another set of coils is called into play, and so on,—a sort of tread-mill arrangement, as it were,—and in this way, by exceedingly short distances at a time, the car is pulled or lifted by magnetism along levels and up hills.

FROM a thermo-dynamical point of view, the gas engine is a machine which ought to be exceedingly good; but the difficulties in building, especially very large engines, and saving by having the heat produced where used, reduce the efficiency of the engine enormously. In spite of that, recently remarked Mr. James Swinburne, in a presidential address before the Institution of Electrical Engineers, the large gas engine seems likely to oust the steam engine for large powers during the next few years. The best way to get a high efficiency out of a gas engine would probably be to make it compound, exhausting at a temperature suitable for raising steam which, after doing work in a steam engine, would exhaust at a temperature suitable for raising sulphurous acid vapour. But the chances are that Dowson, Mond, or other producer gas will be available at such low prices that the extra steam and dioxide engines would not pay for attendance, interest, and depreciation. With very cheap gas the first thing is to make big engines, the next to make them so that they never break down, and the last thing, to make them efficient. The gas engine may be, comparatively speaking, in the state Watt left the steam engine; but it will doubtless make very rapid advances.

AN item which might be thought to have been strangely ignored in the study

of economies in large modern central steam power stations, of 40,000 H. P. and more, is the cost of water. In most of the newer plants, even where surface condensers are employed in place of the latterly more popular jet condensers, the water of condensation is not used as feed-water, but is allowed to go to waste. With a fair average cost of water from a city supply and corresponding cost of coal and evaporative power, the cost of the water has been figured out to be a little over 10 per cent. of the cost of the coal, and in the case of even a moderately large station this makes a tidy sum in the course of a year. In the large station now being built for the Rapid Transit Railway in the city of New York, for example, with its 100,000 horse-power boiler plant, the water bill has been estimated as likely to be in the neighbourhood of $80,000 per annum. The answer to the question why in these days of fine economies such a waste is permitted, is generally found in the expressed fear of oil being carried into the boilers with the condensed steam, and that thus far no satisfactory guarantee has been available that such condensed steam can be used over and over again without risk of boiler damage. The extent to which such fear is justified is not very clearly defined, but it might very properly be said that there ought to be no reason at all for its existence. Receivers, separators, and filters for the condensed steam ought to admit of such combination and efficiency that they would be profitable investments in the value of water saved. Many small power plants certainly are known to save their exhaust steam, and are apparently having no trouble.

ONE argument that has been made in favour of wasting the exhaust steam in a large plant is that through it the construction and operation of the plant are simplified to a very considerable extent, —that, in other words, the probable net saving in using the condensed steam over again would be so small as to make the installation and operation of any system of water-purifying apparatus an unwarranted expense. In a relatively small station, of only a few thousand horse-power, it is maintained, it is possible, and it is probably good engineering, to go into all these refinements which promise to improve station economy; but when a station reaches 20,000 horse-power and more, it has been thought that the engineers in charge should have the simplest possible kind of station to operate, and a station of that size, built so that there is no likelihood that oil will reach the boilers, will be better operated than the one with the greater complication of machinery.

SINCE last month, when in these columns reference was made to Mr. P. C. Hewitt's invention of a novel static converter, he has announced the discovery of another application of his mercury tubes, which, it is thought, will be of much utility in setting up electric waves for wireless telegraphy. In the more recent arrangements of the transmitting apparatus in wireless telegraphy the high-frequency oscillations are obtained by discharging a condenser across a spark gap formed by two or more metal spheres or discs. The objections to this form of spark gap are that the resistance of the air retards the discharge, and that the metal balls soon become impaired by the action of the current. In the case of the Hewitt vapour interrupter, on the other hand, the resistance of the vapour is very low, and as there is nothing within the tube to deteriorate, it may be relied on to give a continuous service of uniform quality. The operation of this interrupter is based primarily on that "electric valve" property of the mercury vapour lamp which opposes the setting up of a current through the lamp until a much higher electromotive force is applied to its terminals than is required to maintain the current after it has been thus started. In addition, however, Mr. Hewitt has discovered that when the current falls below a certain small value, the resistance of the lamp suddenly rises to its former value.

To utilise these properties of the vapour tube for the purpose named the tube is given in the transmitting circuit the place usually occupied by the air spark gap, in series with the secondary of a transformer and in parallel with two condensers and the primary of the aerial wire transformer. The operation is then as follows:—While the electromotive force of the transformer is rising from zero to the point at which the resistance of the tube will give way the condenser is being charged. At the instant this resistance falls, the oscillatory discharge of the condenser takes place, but as soon as this current falls in value below the critical point, the tube at once attains its normal high resistance. In this way abrupt and rapid, but uniform, charging and discharging of the condensers are obtained, with the important result that the uniform and persistent radiation of electric waves so necessary in syntonic wireless telegraphy should be obtainable. The charging electromotive force may range from 10,000 to 20,000 volts, while the drop in the tube itself is not over 14 volts, this energy being consumed in vapourising the mercury. Hence the efficiency of the tube is very high. Another advantage of the device is its simplicity and inexpensiveness. Highly flattering results are predicted as a consequence of the use of this interrupter in wireless telegraph operations.

OBJECTION has, of late, been raised against the use of the term "flash boilers" in connection with boilers of the small, long-tube, or Serpollet type. These, it has been argued, are not flash boilers at all, though, as the London *Engineer* says, it is not easy to find a better or more compact name. The true flash boiler, according to the same authority, is a very old invention. It consisted essentially of a large cast-iron pot, the major portion of which was kept red-hot, and into the pot water was injected through a rose or sprayer, and, falling on the hot iron, was instantaneously "flashed" into steam. The intention of the inventor was to send in just so much water at each stroke of the engine as would supply steam for the next stroke. In another form of flash boiler mercury was kept at a high temperature, and water was dropped on it to be flashed into steam. These, and a dozen similar inventions, all died a natural death. The Serpollet boiler closely resembles the Herreschoff and several other steam generators, in that it consists of a long coil of tubing, into one end of which water is pumped, and out of which, at the other end, it is confidently expected that steam moderately superheated will issue. Only a qualified success has hitherto been obtained with these steam generators,—they do not in any way deserve the title of boilers.

IF we take a small, thick pipe, continues the *Engineer*, about 120 feet long, and, say, ½-inch bore, coil it closely on itself, heat it highly, and pump water in at one end while we take off steam at the other, certain curious phenomena will now and then present themselves, the causes of which are a little obscure. There are various agencies at work, each producing, or trying to produce, its own special results. Unless these agencies are taken into account, little satisfaction will be got from a long-tube generator. It would, however, be impossible to deal with these matters here in any detail. We can only, within reasonable limits of space, direct our readers' attention to them in a very general way. In the first place, it is clear that highly heated water, saturated steam, and superheated steam traverse the whole length of the tube, and when all things proceed in an orderly fashion we shall find that different lengths of the tube will contain in succession cold water, hot water, saturated steam, and superheated steam. Each stroke of the pump will be followed by the rush to the engine of the precise equivalent in steam of the water sent in by the pump. So far, so well. Theoretically, there is no reason why this should not be the sequence of events. In practice, this result is very often

secured; but, unfortunately, it also often happens that it is not secured, and if any permanent success is to be obtained with this type of boiler it will be by ascertaining and eliminating the cause of trouble. The main cause of trouble is want of regularity in communicating the heat to the water. During trials made years ago by engineers of the United States Navy, it was found that now and then in a Herreschoff boiler the water filled the steam space, and there was nothing but steam in the water space. Things got inverted. In a small-tube boiler, if steam is suddenly generated in the lower part of the tube, it will blow the water above it into the upper part of the tube. The phenomenon is brought about in two ways. The first and simplest is sudden variation in the temperature of the furnace. This is largely avoided by the use of oil fuel. The second, most complex and most interesting, is want of permanent contact between the water and the tube. In other words, it appears to be by no means easy to keep the surface of these highly-heated tubes wetted. It is not so much that the spheroidal condition is established as that some kind of repulsion appears to be set up between the metal and the water. The spheroidal condition may, however, also be set up. Be this as it may, for some reason not fully explained, heated plates are in certain cases not thoroughly wetted by water. Consequently we find that not infrequently violent surging and crackings take place in flash boilers; the production of steam becomes irregular, and the engine may stop or be filled with water. Most makers of flash boilers repudiate the idea that spheroidicity manifests itself. However, there are the facts. At one time the generation of steam goes on with clockwork regularity; at another we have turbulence and priming.

As there is no steam space and no reserve of water in any but the most limited sense of the terms, it is evident that whatever goes on in the pump is immediately reproduced in the boiler, and whatever takes place in the boiler at once affects the engine. Thus, if the pump misses a few strokes, the water level will instantly descend in the tube, the tube will become hotter, surfaces will become dried, and when the pump again throws water, the surface may refuse to be wetted, and so the whole balance is upset. Or, again, the pump may throw too much water, with the result of lowering the temperature, and possibly drowning the engine. In the same way, all going on steadily, the fire is suddenly urged; the result is that the water is now evaporated faster than the pump sends it in, and a large portion of the tube may become dry. In one word, the whole operation of generating steam and working an engine with a flash boiler is an exceedingly delicate physical operation, depending for its success on the maintenance of a precise balance in the relations of the various phenomena, which balance is so often secured that the long small-tube boiler enjoys a great deal of favour with those who thoroughly understand it, while it inflicts untold miseries on those who do not understand it, and are unable to humour its very peculiar and domineering idiosyncrasies.

REFERRING to the paragraph on the resistance of air in fly-wheels and the loss of power occasioned by it, printed in the February number of this magazine, Professor Charles H. Benjamin directs attention to some experiments on the bursting of small cast-iron fly-wheels made by him some time ago in which the wheels were simply speeded up to the bursting point. In the cases of a number of wheels which had transverse flanges in or near the rim, however, it was found impossible at first to attain the desired speed. At about 3000 revolutions per minute the speed would remain constant, and no increase of steam pressure could be made to change it. Becoming convinced that this was due to air resistance on the spokes and cross flanges of the rim, Professor Benjamin had the wheels closed in with discs

of sheet iron, wired together, and revolving with the wheels. After this no further difficulty was experienced, and the bursting speed was reached within two minutes of the time of opening the throttle. Professor Benjamin mentions this as specially interesting because we used to be taught that the air revolved with the wheel and created little resistance. In the case of a 24-inch wheel something like 10 H. P. was absorbed at the maximum attainable speed without the sheet metal casing.

THE movement towards the establishment of an eight-hour working day which was vigorously made for some time past in the United States has, for the present at least, ended in failure. The "Eight-Hour Bill," as it was called, was killed in the closing days of the recently adjourned Congress by the well-directed work of the manufacturing interests throughout the country under circumstances that promise well for future contests over this and other similar measures, and its defeat, for which great credit is due to the National Association of Manufacturers of the United States, has an international interest and significance. The Washington correspondent of *The Iron Age*, in reviewing the result, writes that until within the past year the fight against this bill had been carried on by the leading shipyards and armour-plate makers unaided. Congress after Congress the bill was beaten by the energetic work of these individual interests, but the bill was brought into the Senate at so early a period in the last Congress that it began to seem doubtful whether it could again be defeated. At this crisis the National Association of Manufacturers entered the field and opened up a campaign of the most vigorous character. The entire membership of the association, which now embraces two thousand of the leading manufacturers of the United States in all lines of industry, took an active part in the work. Strong representations were made by members of the association who appeared before the Senate Committee, and these were followed by carefully prepared legal arguments, statements concerning the technical industrial questions involved, and urgent personal appeals by mail and telegraph addressed to members of the senatorial investigating committee and other prominent senators. The effect was what might have been expected from such comprehensive and vigorous work. The senatorial leaders, who heretofore regarded the bill as menacing one or two industries only, at once recognised its wide scope and the great danger that threatened manufacturers in all lines throughout the country, and they thereupon decided to exclude the bill from the parliamentary programme.

AN effective impression was made by the uncompromising manner in which the manufacturing interests have squarely met the issue presented by this bill. The labour leaders have so frequently boasted that the manufacturers, while desiring the death of the bill, would not fight it "in the open," that an impression had come to be entertained that manufacturers feared to antagonise the measure lest it might result in some form of retaliation on the part of the labour organisations. The fearless stand taken by the members of the National Association of Manufacturers, however, has dispelled this impression, and has operated as notice to Congress that hereafter the manufacturers of the United States can be counted upon to treat so-called labour legislation in the same aggressive, business-like manner in which other industrial problems are invariably met.

WHILE the sand-blast as a cleaning agent has hitherto been probably most extensively applied to steel plates and structural work, it has been found serviceable and economical also for other purposes. For example, as outlined recently by Mr. George W. Lilly before the American Society of Civil Engi-

neers, it is used in cleaning iron and brass castings, either by the direct application of the blast or by introducing the sand-blast through the hollow trunnion of the tumbling barrel in which the castings are placed. The inner, as well as the outer, surfaces of castings are thus cleaned, and the sharp lines of the edges are preserved, while the cleaning effected by the tumbling barrel without the sand-blast tends to round off the corners. Its use to clean street railway rails and fish-plates, for cast and electric welding, is familiar. It is also effective in cleaning cut-stone work. One of the large ice-manufacturing companies recently purchased a sand-blast machine for use in removing from its condenser pipes the lime scale formed from the hard water used, while one of the street railway companies has employed it in cleaning about 18 inches in length of a large number of its iron trolley poles, just above and below the surface of the ground. At this point the poles had rusted to such an extent as to weaken them materially, and it would soon have been necessary to replace many of them. After cleaning in this way, a coat of paint was immediately applied, and, soon afterward, each pole was encased in a cylinder of cement mortar tamped into removable forms. The sand-blast has also been used at several railway shops in cleaning the tenders of locomotives before repainting. A great saving of expense is thus effected, and superior work is obtained.

IN a recent paper dealing with electrical fire hazards, Mr. Washington Devereux cited the case of a frame house, supplied with gas, and wired and connected for the supply of electric current, where a flexible drop cord was hung in front of a bureau between two windows. A gas bracket was located beside one window, the pipes to supply the bracket being run under the window, but inside the framework, a joint in the pipe being made directly under the window. A fire occurred, and an examination justified the following conclusions:—The flexible cord had been hung over the gas bracket; the handling of both the cord and the bracket had resulted in the removal of some of the insulation of the cord, thus making an electrical connection between the gas pipe and the bare wire; the current was carried to the gas pipe joint; the contact, being electrically poor, created an arc, punctured the pipe, and ignited the gas.

IT might be expected that the accumulated experience with hundreds of ships of various types would have produced a generally similar and presumably "best" form of rudder for each type, and yet the most striking thing about the whole subject is the diversity of opinion expressed in the forms of rudder to be found in vessels of the same type and the small effect of difference in type of vessel upon individual design of rudder. An interesting contribution to the literature of the subject appeared recently in the shape of a paper read by Mr. J. Foster King before the Institution of Engineers and Shipbuilders in Scotland. In order to ascertain, if possible, the effect of rudder form upon steering, Mr. Archibald Denny allowed some trials to be made for Mr. King in Messrs. Denny Brothers' experimental tank at Dumbarton, and the results of these suggested that a rectangular rudder is the most satisfactory form to adopt, presenting a larger surface at the load line in all conditions of trim, and requiring a smaller stock and working gear, in proportion to efficient area, than any other shape. According to Mr. King, there does not appear to be any sufficient reason, beyond fondness for curves, for the common practice of extending the rudder blade high above the load line. The extra area can have little or no steering value, while it exposes additional surface to shocks from seas and adds unnecessary weight.

WITH regard to the proportion which the rudder area should bear to the size

of a vessel, it is fairly evident that a small rudder which can be rapidly set to a large angle without undue loss of speed, will steer as well as, and perhaps better than, a broad rudder, provided it has sufficient area to steer properly. It is also apparent that the smallest efficient rudder is the most economical, because weight, size of stock, steering gear, etc., are reduced in proportion to reduction in area and consequent working stress. In order to ascertain, if possible, from practice, what is the smallest efficient area in proportion to size of vessel, Mr. King made an analysis of the effective areas of the rudders fitted in a very large number of merchant vessels within recent years, and this shows that with the modern full or approximately square-shaped blade this minimum for steamers of all sizes, speeds, and most forms is apparently one square foot of effective rudder blade to each 100 square feet of immersed middle line plane, *i. e.*, the area given by multiplying length of vessel by draught of water. This figure gives about one-half of the area based on Admiralty practice which is mentioned in text-books, and the analysis shows that there is no tendency in practice to increase, but rather to decrease, the proportion of rudder area with increasing length of vessel.

FROM such data as Mr. King obtained, the idea suggests itself that the action of the screw propeller eliminates to a large extent the influence of fineness of form of hull upon the steering efficiency of the rudder, as it is even more common to find a very large rudder on a fine vessel than on a full one, and small rudders give as bad steering results in the one case as the other. Experience, as embodied in practice, would seem to show that only in steamers which are very broad and full in the after body is it necessary to provide rudder areas of more than one per cent. of the immersed middle line plane, which to some extent is in harmony with the tank experiments, while the minimum for modern sailing vessels and for coasting or other steamers, which require to manœuvre under their own steam at slow speeds in narrow waters, is about 1.4 square feet per 100 square feet of middle line plane. The change in form in sailing vessels within the past half century is apparently responsible for an increase from 1.1 to the present 1.4 ratio.

ELECTRIC mine locomotives are very extensively employed for the haulage of coal on main entries and branch headings, but in the majority of coal mines the cars are still "gathered" from the breasts by mules or horses. Electric locomotives equipped with storage batteries, tried for this class of service, are said also to have proven unsuccessful. According to a paper recently read before the American Institute of Mining Engineers by Mr. W. B. Clarke, it might seem, at first thought, very simple to provide the locomotive with a storage battery of such a voltage that the batteries would receive their charge whenever the locomotive operates from the trolley in the ordinary manner. Since the locomotive would operate from the trolley wire on the main entries and branch headings during at least two-thirds of the time, it might be assumed that the batteries would always be fully charged. In practical operation, however, it is found that the voltage at the locomotive varies continually between very wide limits (on account of the line drop), and when it falls below the potential of the batteries they very promptly discharge into the line and assist the generating station. The practical result follows that it is impossible to keep the batteries charged in this manner, except by maintaining a perfectly uniform voltage throughout the entire system, which would entail an enormous and prohibitive investment for line feeders. A complicated arrangement of voltmeters, ammeters and switches might be employed; but the fact remains that the motorman has but two hands, and they are engaged with the ordinary operating device. Again, it would be possible to regularly charge

the batteries from a separate plant, installed especially for that purpose. But if the locomotive were in continual service (and that is presumably the purpose for which it is intended), the limitations of size and weight would necessitate several sets of batteries. In either case the batteries are expensive, and the cost of maintenance and depreciation for this severe service would be from 60 to 100 per cent. per year. The batteries must necessarily be placed on the top of the locomotive, where they prevent ready access to the motors, and in actual service no little trouble has been experienced by the spilling of the acid solution. Furthermore, the fumes from cells make the occupation of the operator disagreeable in the extreme.

To meet the demand for a gathering locomotive, the engineers of the General Electric Company, of New York, have designed a "cable reel device," so called, which may be applied to standard electric mine locomotives. This device is, briefly, a vertical reel of relatively large diameter, containing a flexible, insulated cable. The end of the cable is connected to the trolley circuit, and the current is conducted to the controller on the locomotive through a suitable contact at the centre of the reel. Iron rails are now quite generally used for room haulage in place of wooden rails, and a single conductor cable with rail return would ordinarily be employed.

In reviewing recent steam engine progress, the *Engineer*, of London, remarks that for several years it seemed that finality had been reached, and that 13 pounds per indicated horse-power per hour was the smallest weight of steam that could be counted upon, save under most exceptional circumstances. But there are makers of steam engines at this moment who would probably guarantee without hesitation a minimum consumption of 10 pounds per indicated horse-power if given a free hand. It must be observed that all the old problems about steam and the steam engine remain just where they were. No startling discovery—indeed, no discovery of any kind in connection with steam—has been made for many years. No new invention has been introduced making for economy, so far as principle is concerned. The mathematician has done nothing for the steam engine. James Watt patented if he did not invent almost every device that the mathematician can suggest for promoting economy. Cylinder condensation and its effects, which some persons seem to regard as a new discovery, were written of by Isherwood in the United States, and the late D. K. Clark in Great Britain, forty years ago. As to problems, there is as wide a diversity of opinion and practice to-day as at any former time as to the value or the reverse of the steam jacket. The engineering mind has not been made up as to whether an intermediate re-heater is or is not serviceable. It has long since been proved that a live steam feed-water heater is a source of economy, but no one knows why. But this ignorance in no way retards the march of events. The modern steam engine is more economical than its predecessor for various reasons. In the first place, it is better made. In the second, it has been demonstrated, according to some authorities in confirmation of theory, in accordance with others in direct opposition to it, that clearance spaces cannot be too small. But the main agent in securing economy at present in vogue is superheating.

In connection with the matter of steam superheating, it has been stated that in one case a duty has been obtained of 9 pounds of steam per brake horse-power per hour with a 300 H.-P. compound-engine using a superheater. Another case, with an old vertical compound engine, working with 100 pounds boiler pressure, and a load ranging between 118 and 166 indicated horse-power, using saturated steam, showed a coal consumption of 3.75 pounds per indi-

cated horse-power-hour, while with steam superheated 102 degrees Fahr. the coal consumption fell to 2.34 pounds. The saving amounted to 37½ per cent. These figures, continues the *Engineer*, call to mind those given by Bourne concerning superheating in the P. and O. Company's ship *Alhambra*, with Lamb and Summers' apparatus in 1859. The actual saving in coal was 39 per cent. In the steamship *Ceylon* a saving of 32 per cent. was obtained, the consumption of coal per day falling from 61 tons to 41 tons. These figures are taken from many referring to various ships. A very curious fact in this connection deserves notice, though it is constantly overlooked. It is claimed for superheating in the present day that its great value lies in the fact that it prevents cylinder condensation, and that this condensation is brought about by the wide range in temperature set up by the extreme degree to which expansion is pushed. But the old steamers just mentioned worked with a pressure of about 6 pounds only and with little or no expansion, and yet the economy secured by superheating was even greater than that secured in modern practice. Why is this? It is to be borne in mind that superheating, after careful and costly experiment, went out of favour. It would do the same thing now were it not that there are available infinitely better materials, better workmanship, and better cylinder oils than were obtainable forty, or for that matter twenty, years ago, and even now it remains to be seen whether superheaters when burned out will be replaced.

A NUMBER of cases are on record where accidents have occurred from explosions in air compressor cylinders, due to the use of too much oil for lubrication, and subsequent ignition of the resulting oil vapours mixed with air on compression. As a means of avoiding such mishaps Mr. William L. Saunders recommends abandoning oil altogether or using it very sparingly, and employing soapsuds for lubrication, either entirely or at stated intervals. Another cause of flaming and explosions in air compressors is that kerosene is occasionally used to get over the trouble of sticking of valves.

A TURBINE driven by hot water is the unusual means of operating a small electric plant at a place called Thermopolis, in Wyoming. According to particulars given by Mr. L. B. Cherry, in the *Electrical World and Engineer*, there are several large hot springs along the Big Horn river, on which the town is situated, and from the river bed itself hot springs bubble to such an extent that for miles the river never freezes over. The waste water from the largest of these springs is used by the Thermopolis Electric Light and Power Company for power. The spring is a hot, seething pool, 20 feet in diameter, and so deep that it has never been fathomed. Sulphurous gas and steam are released at the surface, the effect of which gases is to impart a bluish tinge to the water. The temperature of the water is 138° F. The volume of water is 750 cubic feet per minute, with a head of 48 feet available for power. The power house equipment comprises a 13-inch horizontal turbine, connected to a 30 KW, 1100-volt alternator. Owing to the steam and gas which the hot water gives off when agitated, the turbine had to be placed as near the tail water as possible; otherwise the steam and gas would have partly filled the draught tube. Thermopolis itself is a health resort, with the usual accessories of such places. When the present power plant becomes too small, the available power from the river is to be developed, amounting to about 1000 horse-power.

IT is a common practice at the present time to use draught tubes for carrying away the tail water from turbine water-wheels, thus making it possible to place the turbine above the higher level of the water in the tail race, where all connec-

tions are readily accessible under all conditions. As the suction effect of the water that has passed the turbine and is flowing through the draught tube is practically equal to the pressure that the same flow of water would exert above the turbine, there is practically no loss in efficiency in the use of a draught tube of proper construction, while very decided advantage is derived from the placing of the wheel and its shaft and bearings and all connections where they can be examined without difficulty at all times.

WILLIAM BROWNE COGSWELL

General Manager of the Solvay Process Company, Syracuse, New York

A BIOGRAPHICAL SKETCH

THE first engineering experience which Mr. Cogswell had was in the year 1848, when barely fourteen years old. During that year and the one following he worked with a surveying party on the Syracuse & Oswego Railroad and the Syracuse & Utica road. His natural tastes impelled him strongly towards engineering as a profession, and it is not, therefore, surprising that when his surveying experience ended in 1849 he entered Rensselaer Polytechnic Institute, at Troy, N. Y. He remained with that excellent institution three years, and left it with credit; but owing to an extension of the course no class was graduated in that year. In the year 1884 the degree of C. E. was conferred on him by this institute. Soon after leaving Troy Mr. Cogswell began an apprenticeship in the Lawrence Machine Shop, under the superintendence of John C. Hoadley. He came out of that apprenticeship three years later with a theoretical and practical education in engineering mechanics and physics with their allied branches not often secured in so short a time by so young a man. He had studied and worked with the ardent devotion born of a strong love for his chosen profession, and the result was what always follows such efforts when put forth by native ability under such circumstances.

Returning to Syracuse in 1856, he was selected by George Barnes, of the same city, to accompany him to the State of Ohio to take charge of the machinery of the Marietta & Cincinnati Railroad, at Chillicothe, of which road Mr. Barnes had been made superintendent. He remained in that position only three years, when the railroad became crippled in the financial panic of 1857. The year 1859 Mr. Cogswell spent as superintendent of the Broadway Foundry, in St. Louis, Mo., and in 1860 he returned to Syracuse, and, in conjunction with William A. and A. Avery Sweet, started the works which were the inception of the present Whitman & Barnes Manufacturing Company. Here the breaking out of the Civil War found him, and in 1861 he was appointed Civil Engineer in the United States Navy. In this position he performed an enormous amount of labour in fitting up separate repair shops for five stations on the Atlantic seaboard, and lived at one of them erected on shipboard at Port Royal, S. C.

In 1862 he was transferred to the Brooklyn Navy Yard and placed in charge of steam repairs in that then busy place, where he remained four years. The following two years he lived in New York city. In 1870 he was called to take charge of the completion of the Clifton suspension bridge at Niagara Falls, and at the same time gave his attention to the construction of two blast furnaces at the Franklin Iron Works, in Oneida county.

This brings the record of Mr. Cogs-

well's career down to 1874, and it was a successful one in the broadest sense of the word. In no one of the responsible undertakings in which he had been engaged, or stations he had been called on to fill, had he failed of the most flattering success.

In 1874 came what may be viewed as a turning point in Mr. Cogswell's career. In that year he was solicited to go to Mine La Motte, in Missouri, to take charge of the lead mine of the same name at that point. This mine was then, and still is, owned by Mr. Rowland Hazard, who used all arguments in his power to induce Mr. Cogswell to take this step. There he remained five years, until the spring of 1879, when he decided to remove to Syracuse, though retaining, as he still does, the management of the Mine La Motte lead mines.

After returning to Syracuse, and while in quest of some kind of employment, Mr. Cogswell decided to go to Europe to investigate the soda industry. Through a friend he made the acquaintance of Messrs. Solvay & Co., of Brussels, Belgium, who are the most prominent manufacturers in that line in Europe.

The result was that Mr. Cogswell was given a commission to inspect the various points in the United States where factories would be practical, and report. After the receipt of the report steps were taken for the formation of a company for the manufacture of the various soda products. It was decided that Syracuse was the best point for the works, and they were located there, for it was believed by Mr. Cogswell that rock salt might be discovered in the vicinity. Several experimental borings were made in 1881 and 1883, but without success; but information was obtained which led to experiments in Tully valley in 1888, and the discovery of two veins of rock salt, each about 50 feet thick, at a depth of 1200 feet. The company now receive their entire supply, equal to 1200 tons of salt per day, from the Tully wells. The company also put in a plant of such capacity that a large quantity of saturated brine is sold to the salt manufacturers of Syracuse. The company was formed in 1881, with a capital of $300,000, and the following incorporators:—Rowland Hazard, president; Earl B. Alvord, William A. Sweet, George Dana; W. B. Cogswell, treasurer and general manager. The capital has been increased from time to time as the business has grown.

This great industry has led to the formation of the Tully Pipe Line Company, for conveying brine from the wells to the works, with $300.000 capital, and the Split Rock Cable Road Company, with a capital of $100,000. The production of the works for the year 1902 was 270,000 tons of soda ash, 36,000 tons of caustic soda, and 36,000 tons of bicarbonate of soda.

Mr. Cogswell has received ample honours in his profession, as well as evidence of that confidence from business men which is a tribute to his judgment and his business qualifications. He is a member of the American Society of Civil Engineers, the American Institute of Mining Engineers, and American Society of Mechanial Engineers; a Fellow of the Geographical Society, a member of the Association for the Advancement of Science, and the Society of Chemical Industry, of England.

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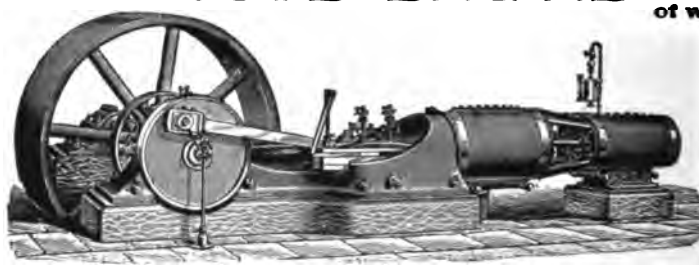

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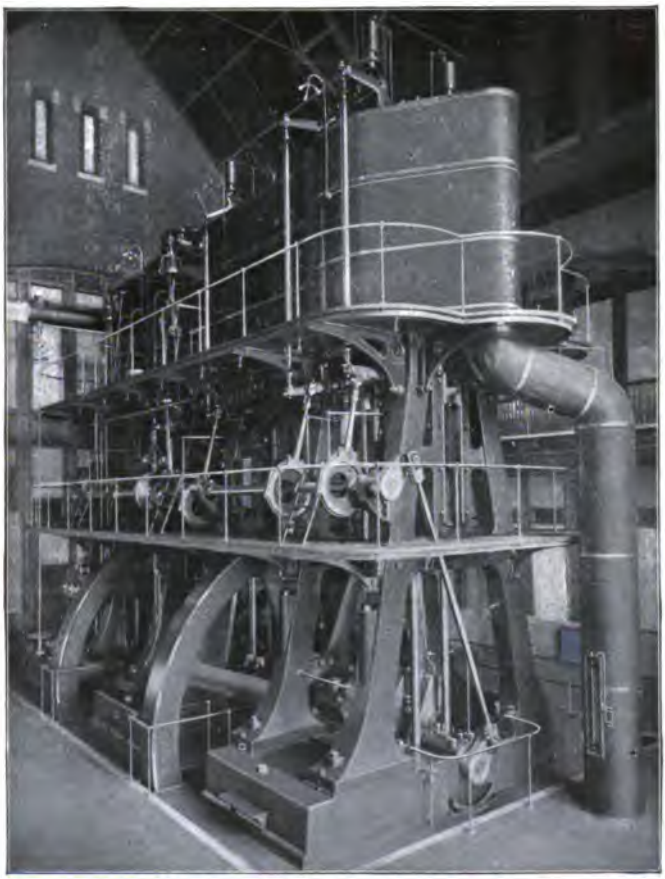

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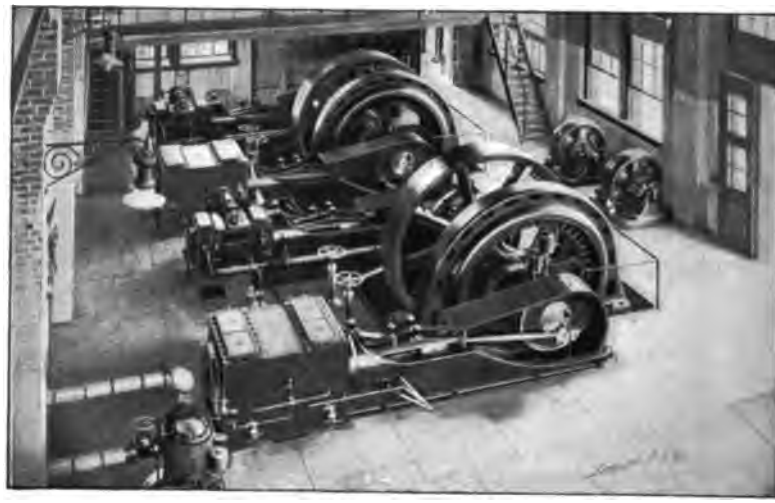

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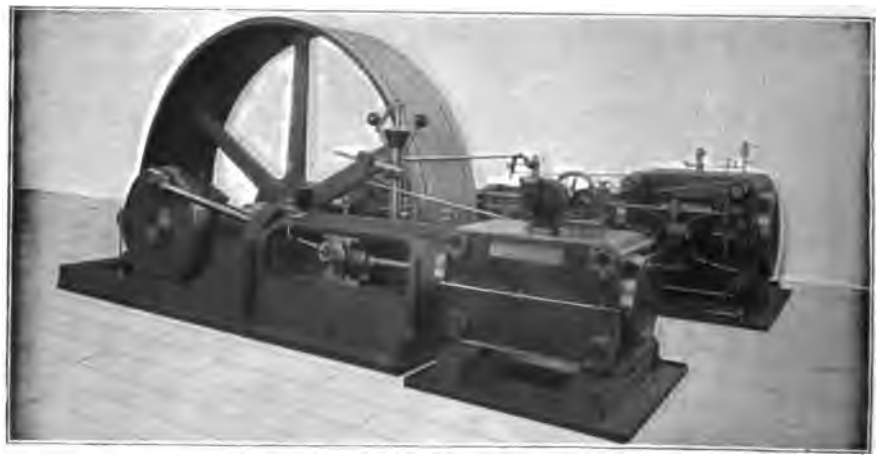

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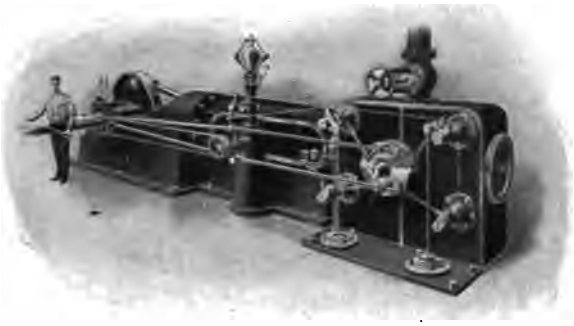

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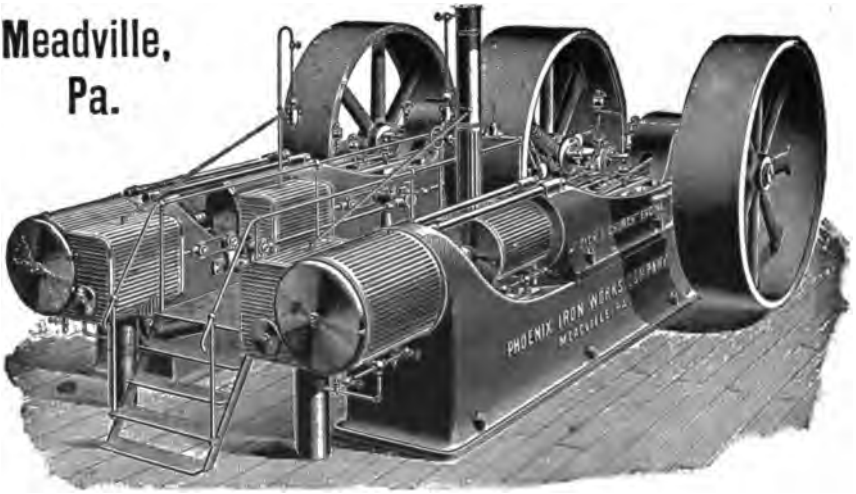

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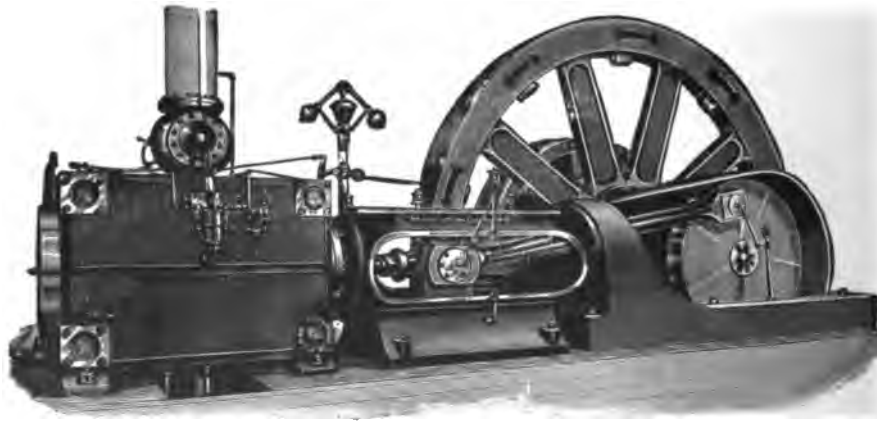

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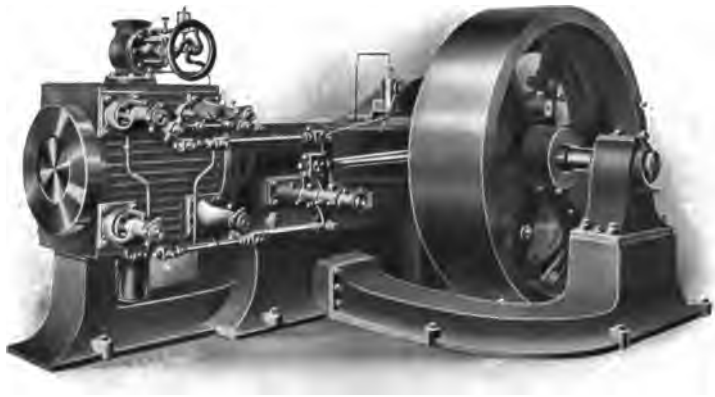

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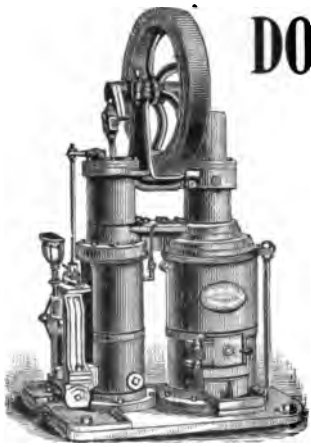

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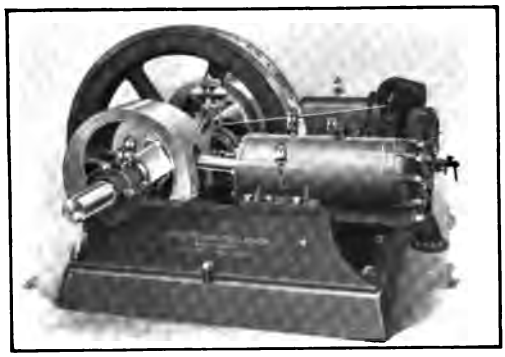

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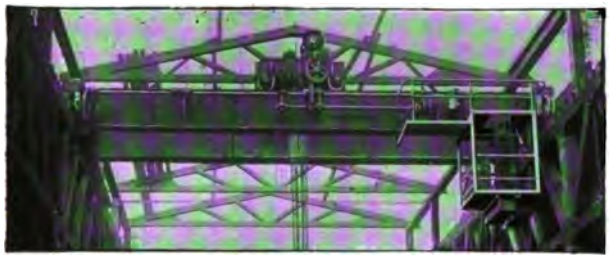

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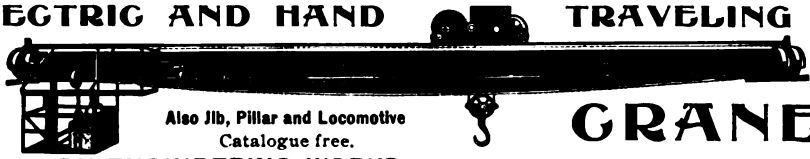

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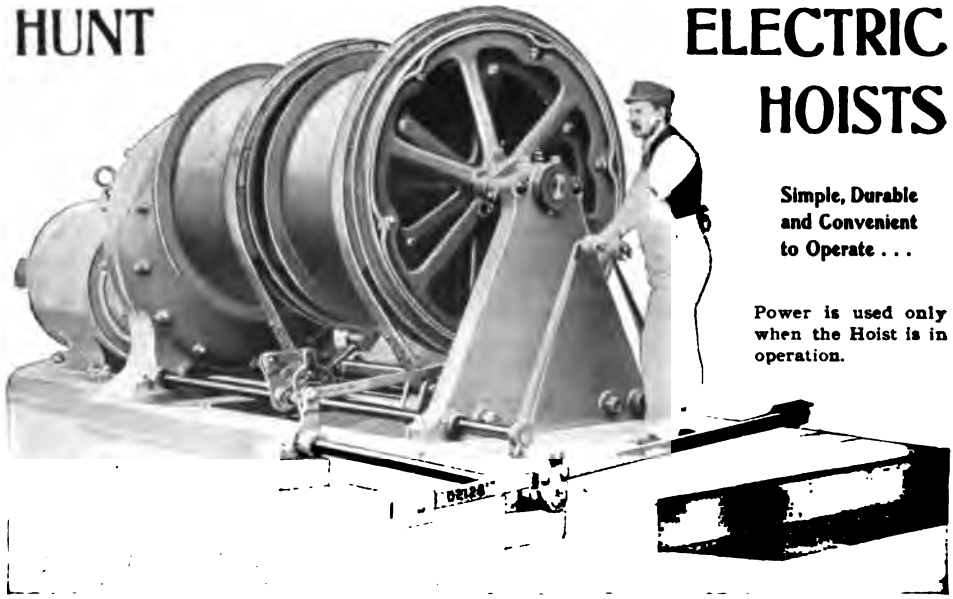

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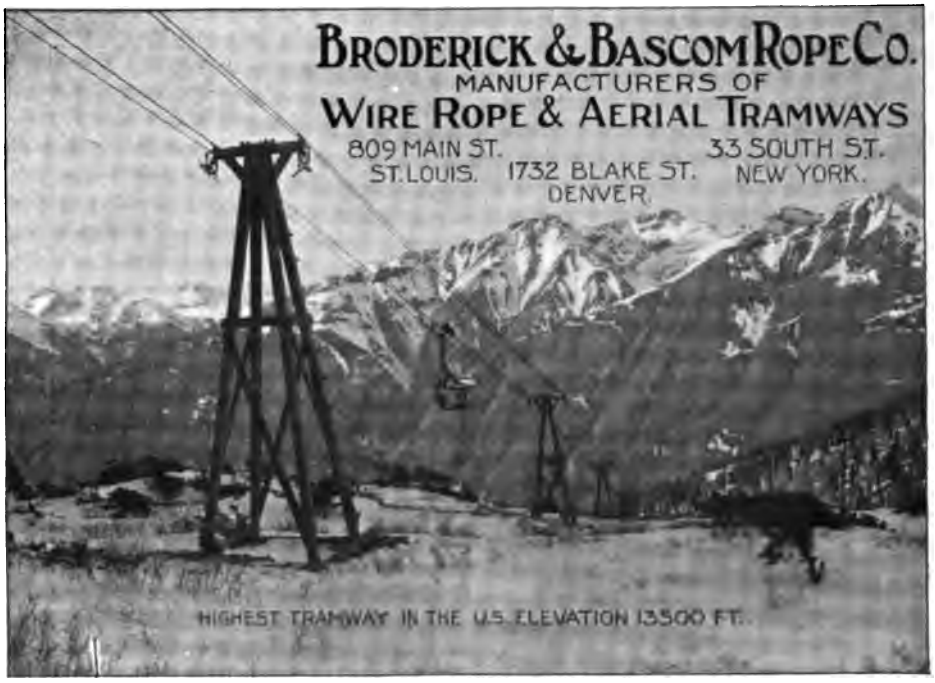
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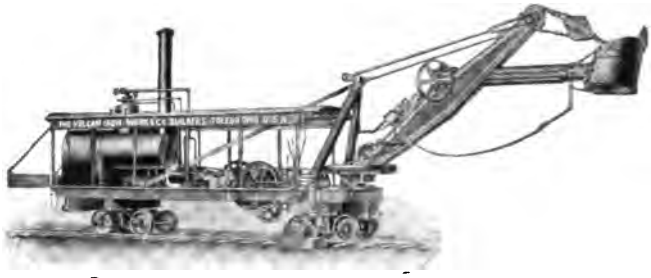

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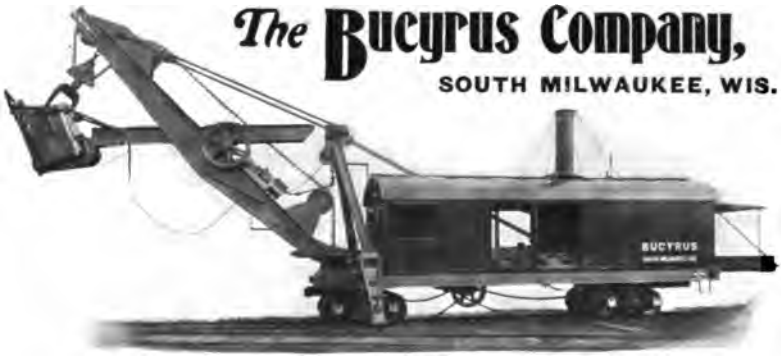

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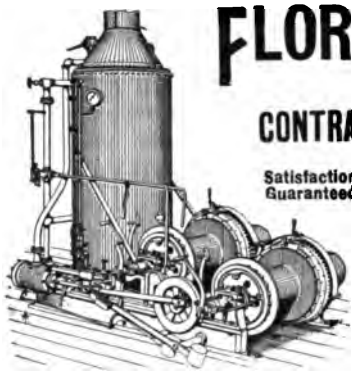

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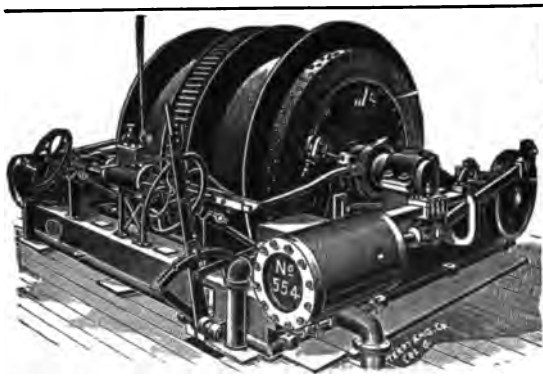

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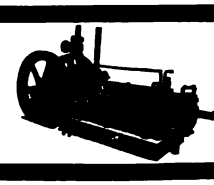

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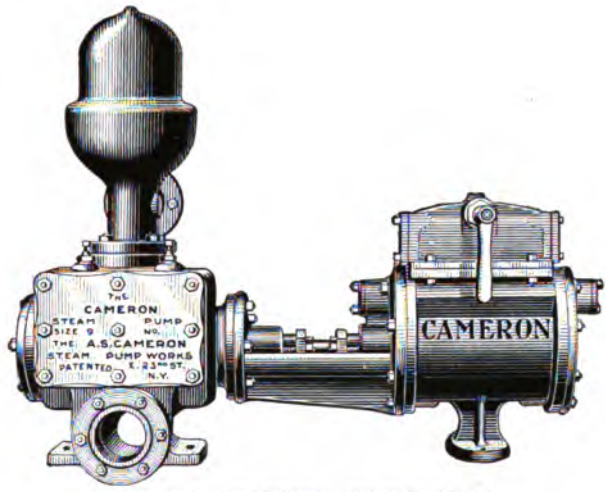

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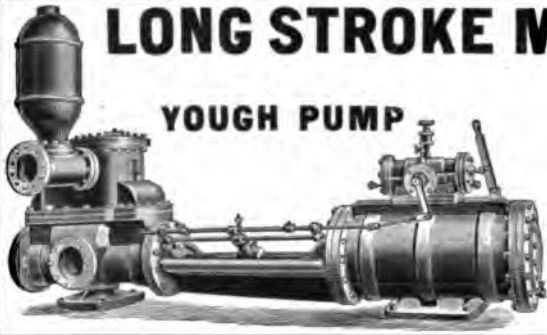

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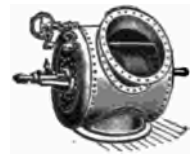

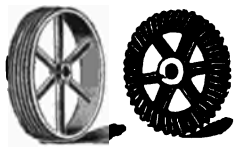

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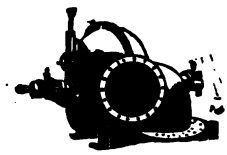

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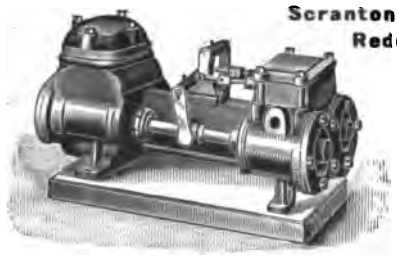

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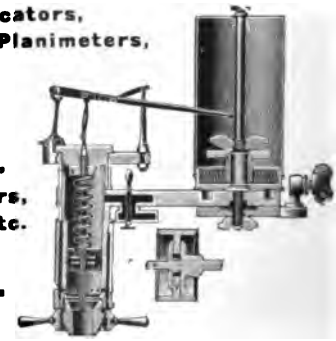

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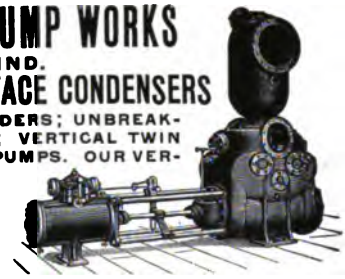

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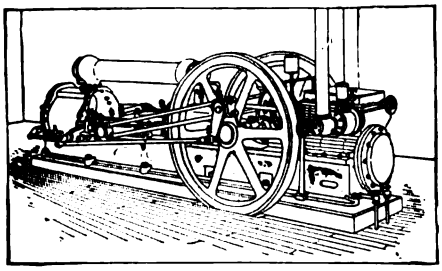

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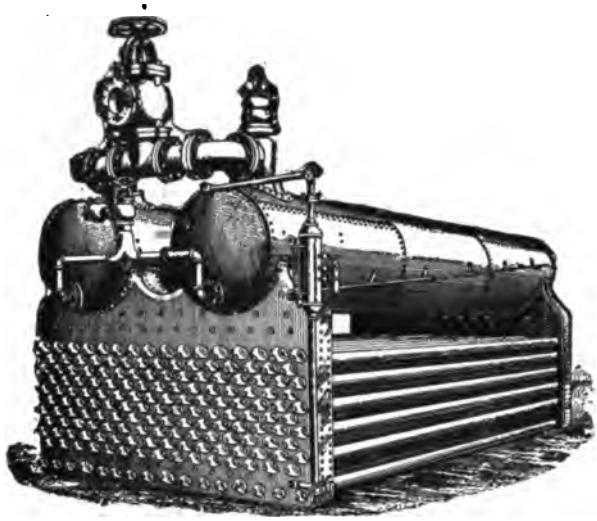

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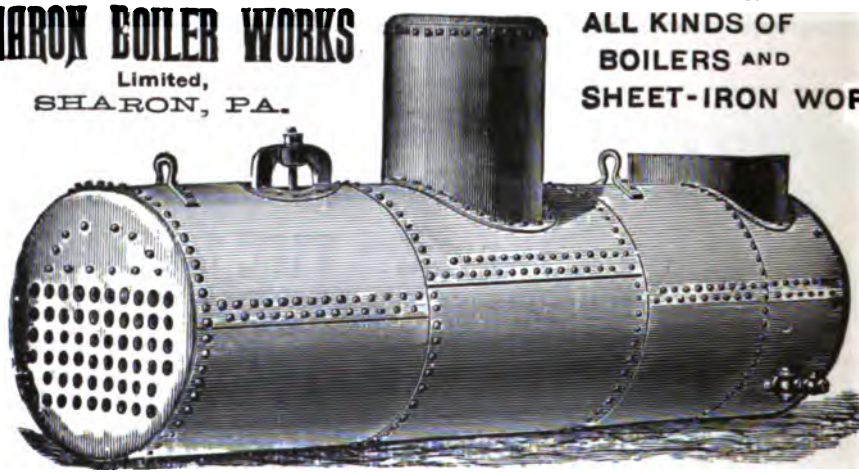

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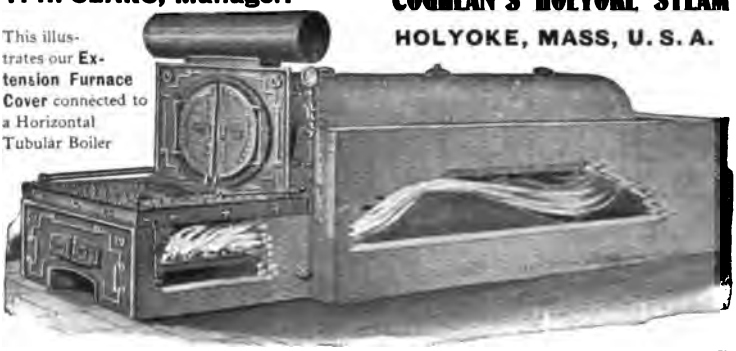

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Extract from "Halifax (Eng.) Guardian" Sept. 2, 1899.

Councillor J. H. Whitley, J. P., Vice-Chairman of the Tramways Committee, and Mr. Street, Electrical Engineer for the Borough, left Halifax, on Wednesday, on a five weeks' trip to America. It is understood that they have gone there with the idea of learning something useful about electric tramways, which have been developed to a much greater extent in America than in this country. Some members of the Council, we hear, have suggested that they could have learned quite as much by reading the excellent articles that have recently been appearing in "Cassier's Magazine" as they will do by going to America.

The trip, will, however, be a very enjoyable one, and perhaps there is quite as much justification for it as the journey that is being made by a Bradford Corporation deputation to Roubaix to inspect certain sewage works. But, of course, the ratepayers grumble about the unnecessary expense in both cases. If they were only members of the deputation they might see things differently. By the way, some people are curious to know why the Vice-Chairman of the Tramways Committee is being sent instead of the Chairman. Perhaps he is able to stand salt water better.

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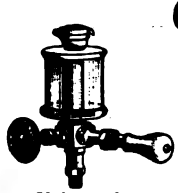
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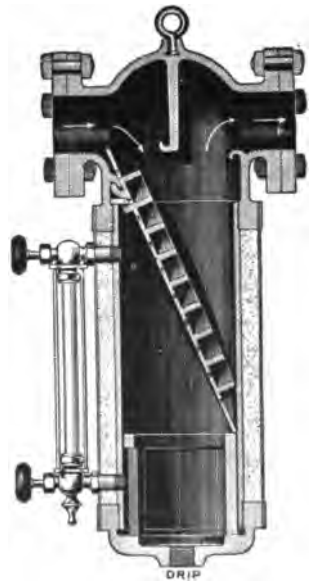

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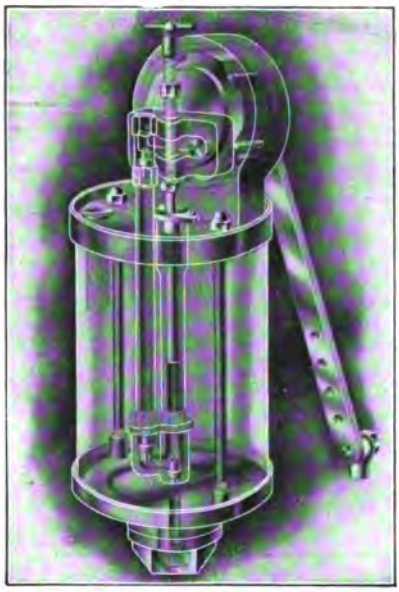

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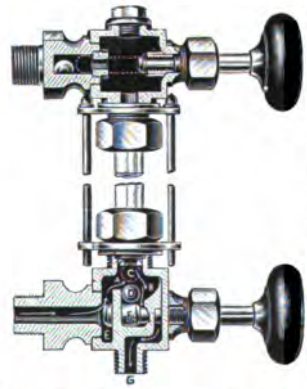

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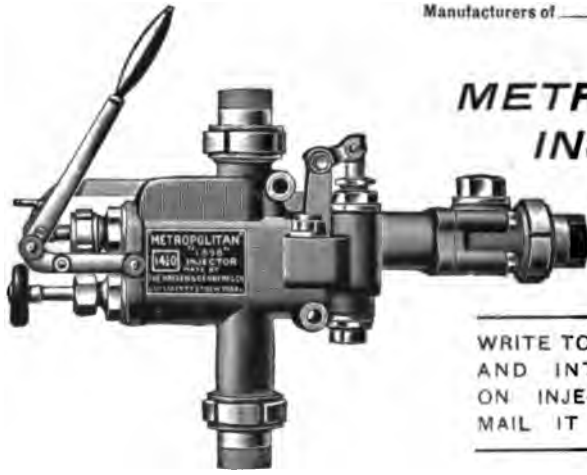

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